SOUTH AUSTRALIA.

DEPARTMENT OF MINES.

Geological Survey of South Australia.

BULLETIN No. 10.

The Building Stones of South Australia.

By R. LOCKHART JACK, B.E., F.G.S., Deputy Government Geologist.

Issued under the authority of
The Honorable T. PASCOE, M.L.C., Minister of Mines.

ADELAIDE:
R. E. E. ROGERS, GOVERNMENT PRINTER, NORTH TERRACE.

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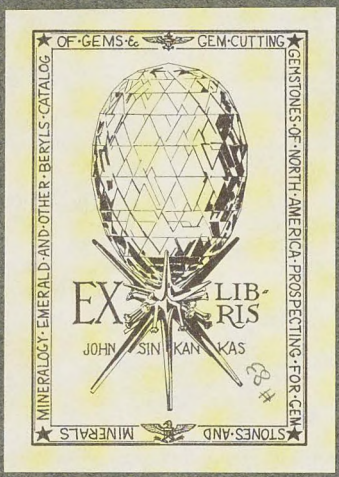
OF·GEMS·& GEM·CUTTING
GEMSTONES·OF·NORTH·AMERICA·PROSPECTING·FOR·GEM
STONES·AND MINERALS
MINERALOGY·EMERALD·AND·OTHER·BERYLS·CATALOG
EX LIB-RIS
JOHN SINKANKAS

Mackay's Polyzoal Limestone Quarry, Section 140, Hundred of Blanche.

Roofs and Ceilings' Polyzoal Limestone Quarry Section 134, Hundred Blanche.

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Geological Survey of South Australia,
Adelaide, March 12th, 1923.

Sir—I have the honor to transmit to you the report of Mr. R. Lockhart Jack, B.E., F.G.S., Deputy Government Geologist, on the Building Stones of South Australia.

This report deals with an important part of the mineral resources of the State, but includes only the materials of construction that are used in the condition in which they occur naturally. A commencement has been made already with the investigation of other mineral substances, such as clays, limestones, sands, and cement materials, used in building; and the results of this work will be published at a later date, to supplement the information here presented.

I have, &c.,
L. KEITH WARD, Government Geologist.

The Honorable T. Pascoe, M.L.C., Minister of Mines.

Submitted for approval to print as a Bulletin of the Geological Survey of South Australia.

Approved,

March 13th, 1923. T. PASCOE, Minister of Mines.

To the Government Geologist, Adelaide.

Sir—I enclose herewith my report on the Building Stones of South Australia.

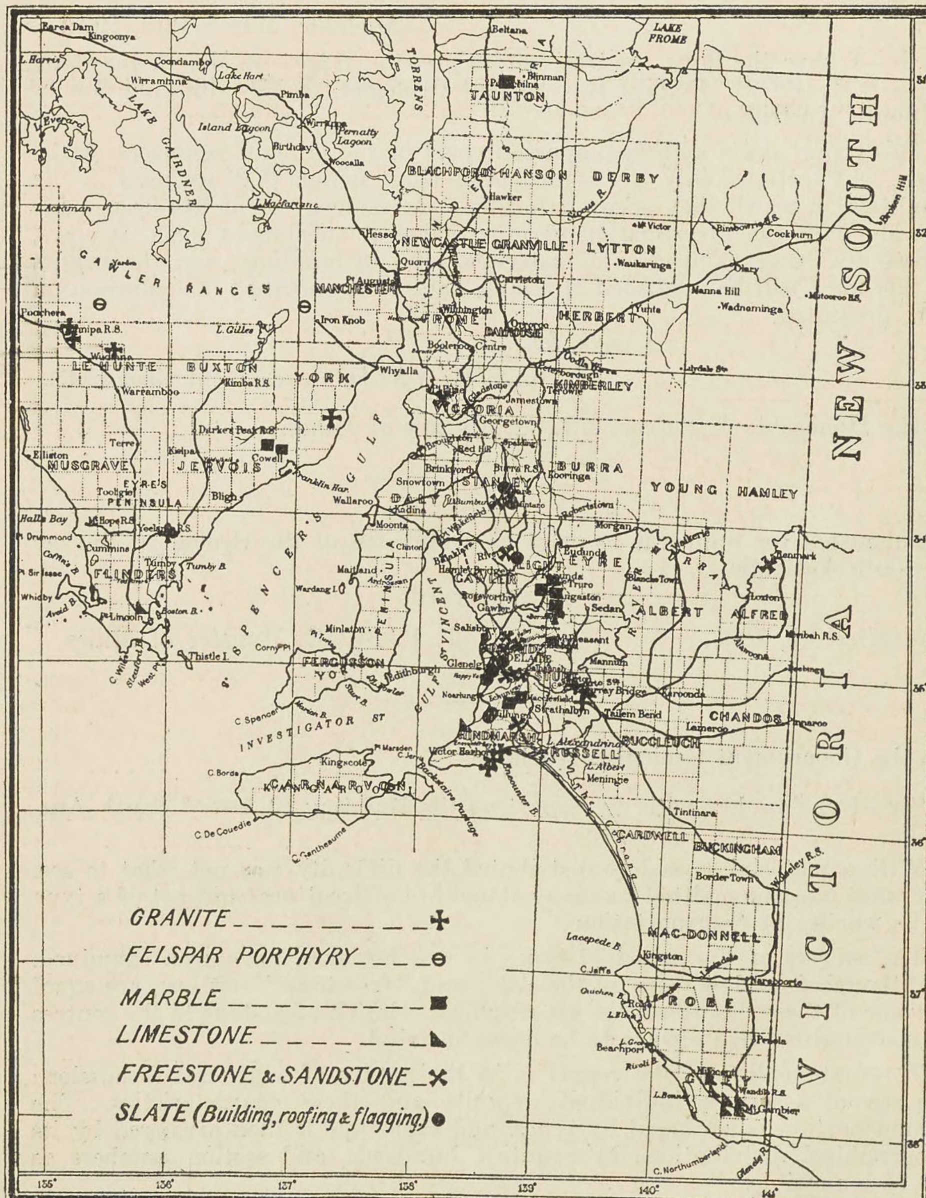
With a material so widely distributed the difficulty was not what to see, but what must be omitted, as many stones are of local use, and not of a type to be worthy of transportation.

The sources of the principal types in use, however, have been examined, and though doubtless many of the slates and "freestones" not seen are equal to some of those described, the geographical relation of a stone to the centres of consumption had always to be borne in mind.

The first portion of the report is in the nature of a general discussion: the second describes individual deposits and their characteristics. The second portion is arranged by types, and each type is then arranged by its geographical distribution: by counties, hundreds, and section numbers as far as is possible.

The analyses are all by Mr. W. S. Chapman, Departmental Analyst. Many have been made in connection with this examination, but a number have been done in the course of other work during several years past.

I have, &c.,
R. LOCKHART JACK, Deputy Government Geologist.



Locality Plan.

The Building Stones of South Australia.

In South Australia the abundance of stone suitable for building, and the comparative lack of easily worked local timber, at a very early date determined the choice of building material, so that the use of stone is very general throughout the State.

The climate has also had an influence on the choice of building material, thick walls being desirable to exclude the heat of summer. At the same time, though frosts are not unknown, it is very improbable that anywhere in the State is the cold so intense and prolonged as to have a disruptive effect upon any stone used for building, through the freezing of water in the pores.

The chief local agencies of destruction of a building stone are the high diurnal temperature of summer, the rains—for the most part light—of winter, and the prevalence of salts in the soil. Climatic conditions are thus exceptionally favorable to the durability of stone, and, as a result, a great deal of latitude is possible in the selection of a material for domestic buildings. Accessibility, ease of working, and low cost appear to be the governing factors in the selection of a stone. In the hilly country, which is mostly occupied by the Pre-Cambrian and Cambrian series of rocks, slates, clay slates, and thin-bedded argillaceous limestones are very common, and a very large proportion of the buildings in these districts are constructed from material obtained from a specially opened quarry in the vicinity.

Another feature influencing building is the very extensive development of a superficial crust of travertinous limestone. This is formed either on the outcrops of bedded limestones by re-constitution in place, or is formed over slightly calcareous rocks or soil, by capillary action (induced by active evaporation) bringing up the lime-impregnated rain waters to deposit their mineral load as a crust a few inches below the surface. Such travertines are quarried easily and in sizes suitable for rubble walling, and, in addition to providing a very fair building stone, are burned for lime. No mention need be made of these two classes of stone, other than where there has been what may be described as "mass consumption," such as has been the case in some country towns and in Adelaide, where various types of the thick clay slates and the thin-bedded slates have been very extensively used with pleasing effect in the construction of residences and of public buildings.

Special stones find local vogue that causes them to be used in some quantity in country towns, or even to be transported for some little distance and brief descriptions will be given of these.

A limestone, locally known as "swamp stone," is worked about seven miles from Port Lincoln. Exceedingly soft when first quarried, it is shaped with a tomahawk, and becomes hard and durable with the loss of its quarry water. Other examples of special local stone are the sandstones of Spring Cart Gully, near Renmark, and the soft, decomposed slate so extensively used in the north for railway buildings and residences.

The bulk of the older existing stone buildings of Adelaide, both public and private, were constructed of either the thin bedded slate of Tapley's Hill, or of the thicker slate typically developed at Glen Osmond and Mitcham. The thicker slates, normally blue-grey in color, break readily to bedding planes, and are traversed by two joint systems almost at right angles. The jointings and bedding planes give stones that are fit for

random-coursed rubble walls with very little hammer trimming. The joint planes are coated with iron and manganese oxides, and when the stone is laid on its bed a very pleasing effect is produced by the color variations which range through the blue, grey, and buff of the slate to black, browns, reds, and ochres of the joint stainings.

Of recent years these slates have not been used to the same extent as before, the trend of fashion apparently demanding a lighter-colored material, such as the Mount Lofty sandstones, or the Polyzoal limestone of Mount Gambier. Brick and reinforced concrete work are also becoming increasing factors.

Marble and sub-crystalline limestone is extensively developed in the State, and many important public buildings and other structures are built of marble. Such instances as Parliament House, the Roman Catholic church at Strathalbyn, the Clarendon weir, and the greater part of Angaston may be cited as examples. The marbles have been worked on a moderate scale for many years for building material and monumental purposes. In the districts where it is quarried, numerous examples of marble residences may be seen, but in Adelaide, as far as the writer is aware, it is only used in subsidiary amounts in residences. In public and semi-public buildings it is used to a greater extent, but there is still room for expansion in this respect.

Granite has also been used with pleasing effect, chiefly for bases, in many of the buildings in the city. The principal localities are Swanport, West Island, Mobilong (Monarto granite), and Tungkillo (Palmer), but other fine granites are available, though perhaps less accessible. One in particular, a dark-grey granite with a pink tinge, is worthy of attention. It is situated on section 5, hundred of Moody, and is exposed by a railway cutting 62 miles from Port Lincoln.

VALUE OR REQUISITES OF A BUILDING STONE.

The value of a building stone depends on the following main factors:—

(1) Suitability for the work to be done on it and by it.
(2) Durability.
(3) Color and permanence.
(4) Cost of preparing the stone up to the fixing in position.

Suitability for the Work to be Done on it and by it.

The many purposes for which stone may be used in a building determines the choice of stone. Whether the stone is to be used internally or externally, whether rough-dressed or polished or a combination of these, or whether great weights are to be supported on columns or foundations, must all be considered.

Durability.

This includes resistance to destructive agencies other than the normal weathering or decay,* such as fire and the abrasion due to heavy traffic

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* The life of a building stone is defined by Ries ("Building Stones and Clay Products") as "the length of time a stone will stand exposure to the weather without showing signs of disintegration and decay." Buildings were examined with this definition in mind.

The agencies of decay that affect the life of building stones in place are well set out by J. A. Howe, "Geology of Building Stones," and the following account of these agencies is condensed from his work, with comments by the writer as to the modfications due to the Australian climate and conditions.

Chemical Agencies of Destruction.

Rain water, which normally carries a proportion of oxygen and of carbon dioxide, attacks many of the rock-forming minerals. It produces the oxidation of the ferrous minerals, with consequent change of color, and, to a less important extent, of volume. Limestones and dolomites are dissolved, and in cities the increased amount of carbon dioxide, and still more important, the sulphuric acid, produced by the combustion of coal, may have an important effect on these building stones or on sandstones with a calcareous cement. In Australia the lesser amount of coal used for heating, and the general low degree of humidity of the air, tend to reduce the amount of decay produced by these two acids. The dust of cities, containing, as it does, a considerable proportion of organic matter, is, when damp, an active destructive agent for such stones as are affected by the organic acids set up by its decay.

Lichens produce both mechanical and chemical effects, but the climate is for the most part, inimical to their growth.

A physico-chemical effect is produced by the introduction of saline material into the walls by the upward rise of moisture from the earth. Portions of South Australia contain very considerable amounts of salts in their soils, and the rise of salt-damp and the destruction of lower courses is well marked. Many of the older walls of travertine in North Adelaide show the effect. An inspection of many of the older buildings of Adelaide in which Tapley's Hill, Glen Osmond, Tarlee, and Auburn slates have been used as base courses or from the ground upward, shows that all these stones are unsuited for these positions unless they are absolutely undecomposed. Any "soft" or decomposed stone is affected by the salt damp, and exfoliates and softens, so that the splash from pavements, abrasions, and wind rapidy erode the soft stone. The mortar appears to be attacked also, perhaps by the mechanical effect of expansion of the exfoliating slate. There are many examples where the lowest portion of these slate walls have had to be protected by cement. Some of the Aldgate freestone also exfoliates very badly in similar positions. An example of this is to be seen in the abutments of the Morphett Street Bridge. The remedy is the use of non-porous hard rock for the foundation courses, or the use of an efficient "dampcourse" material.

The effect of salts is also very marked along the sea front, where walls of inferior brickwork have had the individual bricks so destroyed by the crystallisation of the salts that they are deeply recessed into the mortar.

Mechanical Agencies of Destruction.

Wind may drive dust, sand, and even grit against the lower courses of a building, and cut it away by the abrasive action of the sand blast. There is also friction or abrasion, such as is produced by traffic on steps or pavements, which limits the choice of stone for such purposes. Even the hardest stones when used as treads show the influence of heavy traffic, and may become so dangerously smooth as to require roughening from time to time.

Change of Temperature.

Change of temperature affects the durability of stone, which is a bad conductor of heat, by setting up strains between the surface and the interior of the stone, owing to the difference in the amount of expansion produced on the surface and in the interior of the stone. The effect of temperature changes is well seen in the drier portions of the State, where large flakes or layers are loosened from the underlying rock, and rock masses on the surface are split. There are instances of the flagstones, which have been subjected to extreme temperatures, having scaled superficially.

The minute fracturing that is also caused by temperature may have no visible effect on stone, but is sufficient to permit the absorption of water. In colder climates than Australia such water, on freezing, assists in the disintegration of the stone.

SOUTH AUSTRALIAN STONES AND THEIR DECAY.

The chief groups that may be considered are:—

(1) Slates.
(2) Limestones and marbles.
(3) Sandstones and freestones.
(4) Granitic rocks.

(1) A good deal of the slate used as a building stone in smaller buildings is semi-weathered, as evidenced by the change in color from the dark blue-grey of the fresh rock, but little difference is to be seen in the wearing qualities of the stone so far, except near the ground, when it is affected by salt damp, splash, and dust abrasion. Some of the slates are calcareous, and they may be expected to weather more rapidly, owing to the solution of carbonate of lime and the leaving of ferrous iron in the argillaceous matter exposed to the oxidising action of the air. The thin-bedded Tarlee slate has certain beds in which fretting is pronounced owing to the softness of the stone. The worst, which is exceedingly pervious, shows a tendency to exfoliate, as if by the crystallisation of salts.

(2) Limestone and Marbles. Three subdivisions may be considered:—

(*a*) Travertine.
(*b*) Tertiary limestone of Mount Gambier and Murray Bridge "freestone."
(*c*) Palaeozoic marbles and limestones.

(*a*) The chief enemies of calcareous building stone in South Australia are chemical action of carbonic acid in rain and to a small extent the presence of sulphuric acid from coal in Adelaide. The proportion will increase as the use of local lignite, with its high sulphur content, comes into vogue. Salt-damp also was noted to have a disruptive effect on some of the travertine; the chemical action is not discernible, as the material is invariably used in rough or hammer-trimmed form.

(*b*) The tertiary limestone of Mount Gambier is an exceedingly open-textured stone (a nail may be driven into it without splitting the block). Undoubtedly highly absorbent, it must be affected by the acids. The open texture permits of ready drying of the stone by the air, and the dissolved

carbonates are deposited in the pores near the surface, causing superficial induration. Probably there is no example of the effect of sulphuric acid upon it known, as the districts in which it has long been used burn wood. The very large pore space is sufficient to permit of the 20 per cent. increase in volume due to the change from carbonate of lime to gypsum, so that there should be no disruptive effect. It should be resistant to the small amount of frost likely to be experienced anywhere in Australia.

The Murray Bridge "freestone" is a finer grained and denser facies of the polyzoal limestone, containing larger shell fragments that weather slightly more slowly than the matrix. The durability in many Adelaide buildings is good, and the chief disabilities are the presence of occasional clay aggregates, which weather out and leave cavities which required to be "stopped," and the proportion of waste to be removed in quarrying. Its behaviour should be followed by the Mount Gambier limestone, though the latter will not be quite as durable. Deeply incised carving and delicate members should not be attempted with these stones for external decoration.

(*c*) The Palaeozoic limestones and marbles.

Dense and comparatively non-absorbent, these stones appear to be but little affected by chemical factors in South Australia, and give every indication of permanency. Some of the marbles have small and local developments of crystal pyrite, which, on decomposition, cause rust streaks that mar the appearance of the stone. It is very rarely in sufficient quantity to be of consequence in this respect, and as far as the stone in use is concerned, has no practical effect in chemical decay.

(3) Sandstone.

The siliceous aggregate making up a sandstone may be regarded as indestructible, the source of weakness lying in the interstitial filling.

The local sandstones vary considerably in type, and may be roughly classified as:—

(*a*) Freestone.
(*b*) Sandstones with calcareous cement.
(*c*) Sandstones with argillaceous cement.
(*d*) Sandstones with siliceous cement.

These stones weather in accordance with their cements.

Much of the freestone is semi-decomposed felspathic quartzite that has become softened through the decomposition of the felspars so that the cement is more or less clayey in its nature.

Some of the highly felspathic quartzites yield a soft and workable stone near the surface, owing to the decomposition of the felspars, and this class is the source of all the chief supplies of freestone and sandstone. They become harder and more durable as depth is attained, and the stone is less and less decomposed until it is unworkable.

Sandstones with siliceous cement (or quartzites) are exceedingly durable, but unless they break to useful sizes along bedding and joint planes are not much used.

(4) Granites.

Chemical agencies may be disregarded in the case of granites under Australian conditions, temperature changes being the most potent form of disruption.

SUITABILITY OF VARIOUS STONES.

The general consideration of the suitability of stone is most difficult, owing to the factors that must be assumed. To take the case of Adelaide, in which examples of most of the stones worked are to be found, the type of building will determine the stone permissible, apart from the question of cost.

For the high modern city or public building, in which resistance to crushing, safety, and fire, and permanency are important, only the highest quality stone should find a place. This postulates the use of the marbles of Angaston and Macclesfield, the grey and red granites; the "freestone" of Murray Bridge, and the freestone of Teatree Gully. The latter type may be confidently expected to occur deeper down in the beds that yield the soft kaolinised felspathic quartzites worked in several localities as freestone, and which source of supply is at present untouched. With these for many purposes must be included the Mintaro flagstones and the Willunga slates.

Buildings not exceeding about four storeys may be constructed of the Tapley's Hill, Glen Osmond, Auburn, and Tarlee slates, and some of the denser freestones of Mount Lofty, Sheaoak Hill, and Stirling. As far as strength is concerned, the Mount Gambier limestone might well be used for this class, but the porosity of the stone and the consequent necessity of building with cavity walls introduces a method of construction that would probably limit the height of the building.

For two-storey buildings and cottages the majority of the stones quarried are suitable, and the choice of material depends on individual taste, cost, and location rather than on the strength of the stone. Some of the freestones that are worked for this class of building are exceedingly soft when quarried, and there are one or two examples that should not be used for walls exposed to the wash of rain, owng to their great friability. As a class the freestones harden remarkably as they lose their quarry water.

More might be done in the smaller buildings to use marble, which is abundant close to the railways, and which can be obtained almost as cheaply as any of the other stones in the medium-sized irregular blocks that are generally designated as "builders." No comment need be made as to the quality and durability of such marbles. Dressing or scabbling to "rock face" would certainly be more expensive than with the very easily worked freestone.

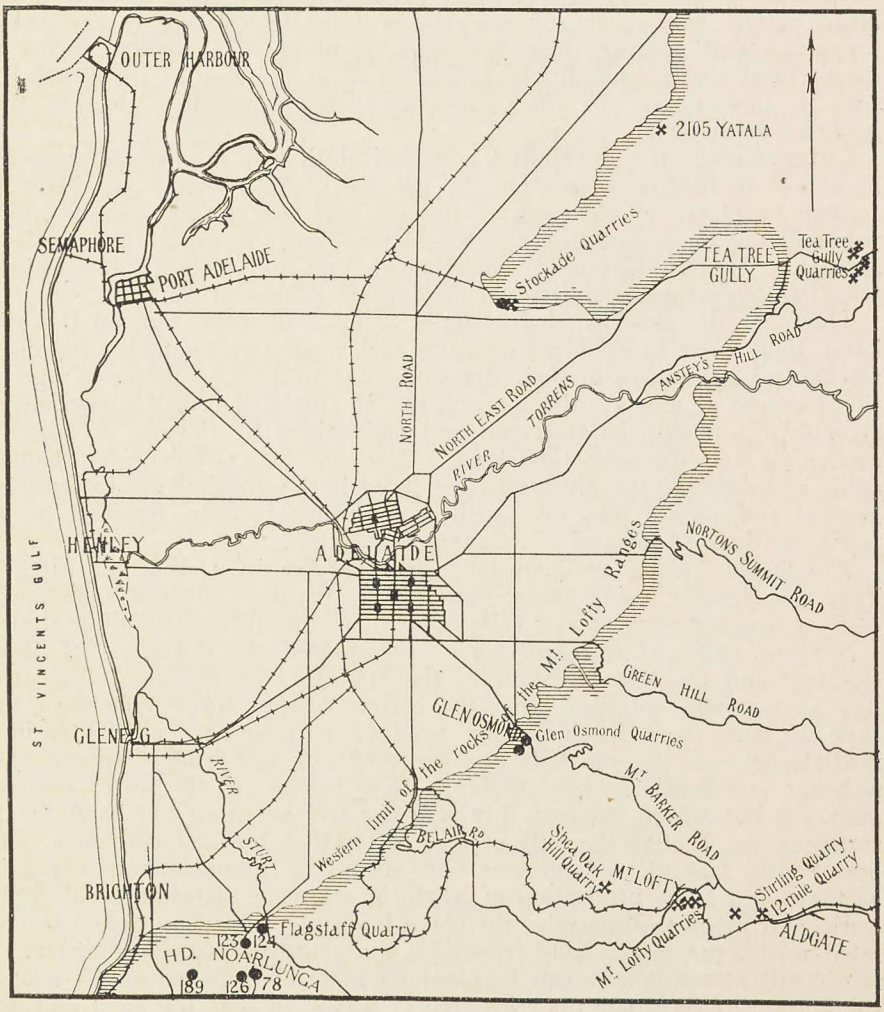
If the possibilities of export beyond the limits of the State are considered, it is apparent that only special grades can stand the freights incurred or the competition of sources of supply closer to the demand. Both the Macclesfield and Angaston marbles find markets beyond the limits of the State, and are exported in sawn and polished slabs and in the rough blocks. The serpentine marble found in the hundred of Minbrie, near Cowell, is also worthy of use beyond the State. The freights vary with the amount of work done on the stone, to the detriment of the local marble dressing industry.

The same freight conditions apply to slate, which is exported to the eastern States as flagstones and as roofing slates.

The granites do not appear to have an equal prospect of an export trade, not that they are in any way inferior to their competitors in the other States, but because the latter have supplies of granite within their boundaries, and freight rates will determine the source of supply.

Murray Bridge "free stone" (limestone) might well find a market, if not in Melbourne, in some of the towns on this side of it.

The Mount Gambier stone, which is now being extensively worked, is railed to Adelaide on the one hand and to Melbourne on the other. It is sent either as sawn blocks of about 4ft. cube, or sawn to sizes of 4½in. by 12in. by 24in., ready for building cavity walls. This stone has stood



LEGEND

Slate● Freestone & Sandstone × Tertiary Limestone ◣

Principal Roads—— Railways——

The Building Stones in Relation to Adelaide.

satisfactorily in Mount Gambier, and will probably stand equally well in Melbourne in the suburban areas, where it is most likely to be used.

The siliceous freestone or sandstone and the building slates of the Mount Lofty Ranges cannot be expected to be used outside the State. This, however, does not apply to the flagging slate of Mintaro or to the Willunga roofing slates, both of which find their chief market in the eastern States,

in which, so far, nothing capable of competing with them has been developed.

It appears certain that, as in the past, future building construction in South Australia will always be characterised by the free use of mineral substances—stone, clay and gypsum products, and cement—and to a very large extent the choice of material will be determined by the cost of preparing and placing these materials in place. In some districts the use of local stone is absolutely indicated, as in the case of the South-East with its limestones. In other cases, and more especially Adelaide, there is choice of material.

Unfortunately the durability and desirability of any stone appear to be almost in inverse proportion to its cost. The writer considers the felspar porphyry of the Gawler Ranges and the various granites to be very high in these qualities, and would place next in order the marbles of Angaston, Cowell, Kapunda, Macclesfield, and Paris Creek, the ultimate selection depending on individual taste or the nature of the work.

These are the most expensive stones to get and work, but, on the other hand, they occur in sufficient quantity and regularity to justify the use of mechanical appliances in their dressing. At present no power is used for this purpose at any granite quarry, but if any serious call for granite is to arise it can only be answered and maintained by the use of power in quarrying and dressing the stone. The use of power-driven hammer drills and dressing machines must be faced if the granites are to come into general commercial use, and such expenditure is only justified by the fairly continuous demand of a larger population.

The marble, slate, and flagstone quarries are in a different category. They are already using power, and have regular outputs, and can be easily expanded to meet any calls upon them for dressed building stone.

Next in order of durability may be placed the dolomites of Mount Gambier and the best freestone of the Mount Lofty Ranges. The latter has been chiefly obtained from the better Teatree Gully quarries. This type of stone is a decomposition product of felspathic quartzite, intermediate between the quartzite and the very soft and friable freestone that is being so extensively used to-day. It is present in the softer freestone quarries, but where exposed it was being left as being too hard for the stone masons, though the bulk of it is softer than Sydney sandstone. The best South Australian sandstone will always be comparatively expensive, as there is a large proportion of waste in selecting material for first-class work, and in several quarries the stone is deeply buried by either accumulated waste, the soft friable freestone, or by argillaceous overburden. It is difficult to see how it can be obtained more cheaply except by keeping the bottom of freestone quarries free of waste, so that the hard and good stone may be accessible when called for.

After this the writer would rank the slates of the Glen Osmond and Tapley's Hill types in order of durability. Very largely used at one time, they have become unfashionable compared with the lighter colored stones, and their use has greatly diminished. Still, they are easily won, and break readily to convenient sizes, and though the deepest slate is somewhat sombre, the slightly oxidised stone, with its variegated iron-stained faces, has a very pleasing effect. The stone is worthy of greater use, and when it is studied, and the design of building is adapted to the material, as is being done with the light-colored stones, there will undoubtedly be a reversion to it. They should not, however, be used exposed to weather near the ground, unless only the densest and wholly undecomposed blue slate is used, as there is danger of exfoliation.

The Murray Bridge "freestone" is inferior to the slate in durability, but, being light and uniform in color, fairly hard, but capable of being sawn and carved, is one of the most useful and popular of the building stones for high-class work. The proportion of waste in quarrying makes the stone expensive, and it is likely to remain so until a use is found for the waste. For example, a cement plant working such a deposit might very well reserve the best stone for building purposes, or, as would be perhaps more feasible, the utilisation of quarry waste and stripping by burning for lime might reduce the cost and facilitate the working of the quarry. The composition of the limestone given on page 37 shows that it is suitable for either purpose. The compressive strength of the stone is such that it can be used in the highest of city buildings with confidence. It is, however, somewhat brittle when transversely loaded.

Allied genetically to the Murray Bridge stone is the Polyzoal limestone of the Mount Gambier district. It is very porous and less durable than many of the stones used, but is superior to the semi-decomposed slates and the softest freestones. In common with all granular-surfaced stones it darkens with age by the adhesion of dust and smoke. No change of color arises from within the stone. On the other hand, it is very uniform in texture and light in color, and can be quarried, dressed, and erected at a price per cubic foot that is unapproached by any other stone except in the roughest of walling. The light weight per cubic foot compared with other stones enlarges its field of economic utilisation to a marked degree, and there is no doubt but that, as the merits and treatment of this stone are more widely recognised, its use will be greatly extended. It is an excellent stone in its own district, which is fairly wet and cold, and in drier and warmer climates, such as that of Adelaide and the Murray Valley, must come to be highly appreciated, especially when its treatment is not confined to sawn faces. Finally, the fact that it is possible to get blocks of any size that can be transported lends itself to the decorative treatment of the stone.

The relative position of the sandstones and freestones of the Mount Lofty Ranges is difficult to decide. The best of them would be the undecomposed felspathic quartzite from which they are derived, but its exceeding hardness would render the working of anything requiring dressing an economic impossibility. Stone setts for heavy road traffic are the only shaped stones made from this material, and this type of block could only be made for building at such a cost that the builder would probably prefer granite or marble.

The Teatree Gully sandstone, examples of which may be seen in the Town Hall and G.P.O., Adelaide, is the hardest of the workable stone, and is very good indeed. From this standard there is a wide range of stone of increasing friability, coupled with decreasing durability and cost of dressing, until the softest and poorest quality is such that it is little more than coherent sand. It, however, hardens with the loss of its quarry water, and the poorest quality is fairly satisfactory in cottage walls when protected from the wash of rain. Fortunately, as stated before, local climatic conditions are not severe on stone work, and thus the question of relative costs of quarrying, dressing, and carriage has a very great influence on the selection of a stone. At the same time it should be remembered that even in the softest of the freestone quarries there will be high-grade stone between the soft material and the undecomposed portion of the bed.

Finally there comes a very widespread and useful stone, the superficial travertine limestone. It varies greatly in hardness and quality. The best of it is compact, but in general it breaks irregularly on the faces and also on the top and bottom planes, so that a considerable proportion of mortar

has to be used. The quantity is not of very great importance, as the lime is, in many cases, obtained by burning the waste travertine, but it prevents a good finish being given to the walling.

Nevertheless, travertine has been and is much used, especially in the country, as it is easily got in convenient sizes for handling.

Its durability places it considerably higher than the place assigned to it, but the general roughness of walling made from it has caused the writer to assign to it the lowest place among the well-recognised stones.

The question of relative durability has been discussed by the writer at some length, as it has a bearing on the matter of renewals, and with the growth of Adelaide and the inevitable change from wood to coal smoke, the conditions will become somewhat more difficult for building stone. The principal effect will be the begriming of the more granular types, and to a slight extent the increase of chemical action of carbonic and sulphurous acid upon the carbonate rocks.

The bulk of the failures and incipient failures are within 2ft. to 3ft. of the ground, where all the softer slates and some of the freestones are affected by the rise of water and salt from the earth, and by the splash of rain. The freestones and the Murray Bridge stone are affected by water and temperature, and should not be carved deeply or into delicate forms, which in these porous and semi-porous stones are peculiarly susceptible to decay.

DETAILS OF QUARRIES.

SLATE.

COUNTY OF ADELAIDE.

HUNDRED OF ADELAIDE, SECTION 1079.

B. Capper's Quarries (Lessees Stone Bros.).

These quarries are on a bed of slate overlying the Glen Osmond quartzite that is so extensively quarried for road metal.

The slates dip 15° to 25° to S.S.W., and are cut up by joint and cleavage planes dipping 40° to E.S.E. and joint systems dipping 75° to N. x W. and vertical, and striking parallel to the faces of the quarries (W. x N. to E. by S.).

About 15ft. of overburden covers the slate which occurs in beds up to 10ft. and 15ft. thick. The slate is slightly arenaceous, and the bulk of the material is light-grey in color. It is lighter towards the surface, and doubtless with depth will become darker. The joints above mentioned are iron-stained and show yellow, brown, red, and black faces. As the stone breaks to its bedding and jointing these colors are exposed with very pleasing effect in building walls. The blocks won are rather irregular in shape, requiring trimming, and only about 60 per cent. of the stone broken is marketable.

This appeared to be the only slate quarry now working at Glen Osmond although very large quarries have been worked in the past on the thick or Glen Osmond slate underlying the quartzite. These slates have been used very largely in the past in all classes of architectural work, with very satisfactory results when care has been taken to use stone that was not almost wholly weathered. When badly decayed stones have been used the more argillaceous laminae fret out, leaving the surface of the stone grooved.

The softer stones used in base courses show very considerable disintegra-

tion and exfoliation within a couple of feet of the ground owing to the presence of salt damp and splash. The stone is better suited for the higher portions of a building.

No special examples of its use need be cited, as at one time it was in almost universal use, and examples are visible at every turn. It is thick bedded and is easily distinguished from the Tapley's Hill and Auburn slates, which are thin bedded.

Hundred of Noarlunga.

The Tapley's Hill Slates.

The hills lying to the south of the Adelaide coastal plain are composed, in the vicinity of the Main South Road, of an extensive series of rocks known as the Tapley's Hill slates.

The succession and stratigraphical relation of this series to the adjacent rocks has been worked out by Professor W. Howchin (Royal Society of South Australia, Vol. XXVII., p. 253), who shows that the beds are very persistent, and that they occupy the following positions in descending order:—

(*a*) Purple slates, quartzites, and limestones.
(*b*) Siliceous, blue, pink, and dolomitic limestones.
(*c*) *Banded, Fine-grained Clay Slates and Shales.*
(*d*) Glacial till, grits, &c., with erratics.
(*e*) Siliceous and felspathic quartzites and phyllites.

The (*a*) and (*b*) series are recognised on fossil evidence as being of Lower Cambrian age, but recently the age of the glacial till has been under review, and it is possible that it and the overlying thin-bedded slates of Tapley's Hill are of Upper Pre-Cambrian age, and are separated from the overlying limestones by a disconformity.

There are a number of quarries on this slate in an area of three-quarters of a mile across the strike and a mile along the beds, and the stone shows the same general habit. It becomes more calcareous in ascending order and less fissile along the bedding planes. These planes separate thin and very regular beds, ranging from 20 to 30 to the inch, and stand out quite distinctly. The dip varies from point to point from 20° to 45° to the westward.

Approximately at right angles to the dip and parallel to the strike is a well-developed tendency to cleavage. In some places this shatters the stone unduly, but for the most part is of use in enabling blocks to be obtained. In the westernmost quarry this cleavage is more pronounced than the weakness due to the bedding, and in consequence the stone is, in building, bedded, not on its natural bed, but on cleavage faces.

A second system of widely spaced joints occurs at right angles to the cleavage, and in consequence approximately rectangular blocks of large size can be obtained. All the quarries show a third series of joints dipping flatly to the southward. Though infrequent, these "cutters" raise the proportion of waste rock made in the quarries.

Uses.—The bulk of the material is used for residential purposes, a very large number of the older residences of Adelaide being built wholly of this stone, while many of the more recent use a considerable proportion as foundation and lower courses, for which it is well adapted if the fresh, undecomposed bluestone only is used. Examples of its use are to be seen in the base courses of St. Peter's Cathedral and in portion of the University. Barker Brothers' building in Currie Street is an example of its use, but one of the most recent is the southern and eastern faces of the Government

Printing Office, where massive stones have been used, with Murray Bridge "freestone" as a trim. Numerous churches and other public buildings have been constructed of this material, which may be distinguished from the Glen Osmond and Mitcham slates by its characteristic thin bedding, and from the Auburn slate by its cleavage.

When fresh the slate is dark bluish-grey in color and somewhat sombre. After weathering, but while still sound, the color changes to yellowish-grey to fawn. Migration of the iron set free causes the joint planes of the weathered and also, to some extent, of the unweathered rock to be colored various shades of red, yellow, black, and brown, and these in large walls give a pleasing and variegated effect when the joint planes are used as "facers."

Another use that absorbed a considerable amount of this stone is for kerbstone for street guttering, but this use is meeting the competition of concrete, either moulded in place or in the form of slabs. Waste, where the quarry is favorably placed, is used for road foundation work, beneath the wearing surface of Brighton limestone or of quartzite.

TAPLEY'S HILL QUARRIES.

Section No. 77, Hundred of Noarlunga (and Adelaide).

Flagstaff Quarry.

This quarry in the lower portion of the Tapley's Hill slate series is the type locality. The slate is fine-grained and thin-bedded, individual beds ranging from the thickness of a sheet of paper to about $\frac{1}{8}$in. On weathering the bedded structure becomes very apparent, owing to the ferrous iron oxidising to ferric iron. Iron oxides of many colors also face the cleavage and joint planes. The beds in this quarry are very slightly calcareous in the unweathered portions, but as the Tapley's Hill series is crossed to the west, towards the quarry on section 189, Noarlunga, the proportion of lime increases, although the structure and general appearance is but little changed.

The quarry is worked intermittently, and exceeds 150ft. x 150ft. in area, and ranges in depth from 10ft. to over 40ft. The slate strikes a few degrees west of south, and dips 48° to the westward.

The bedding planes are well defined, and every few feet there are some open bedding joints, permitting the separation of the beds. The latter are slightly crumpled, the zones of crumpling following the cleavage planes, which dip 45° to the eastward and strike with the bedding planes.

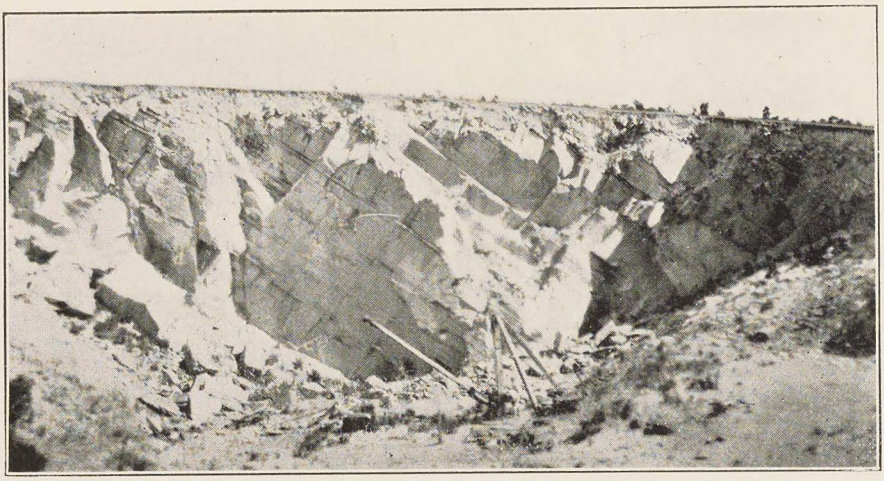
A third system of jointing crosses two series of joints at right angles, and the stone breaks into fairly rectangular blocks, modified by occasional diagonal joints.

Overburden is not great, and the proportion of waste left at the quarry is comparatively small. It is understood that the waste is disposed of to form the foundation of roads.

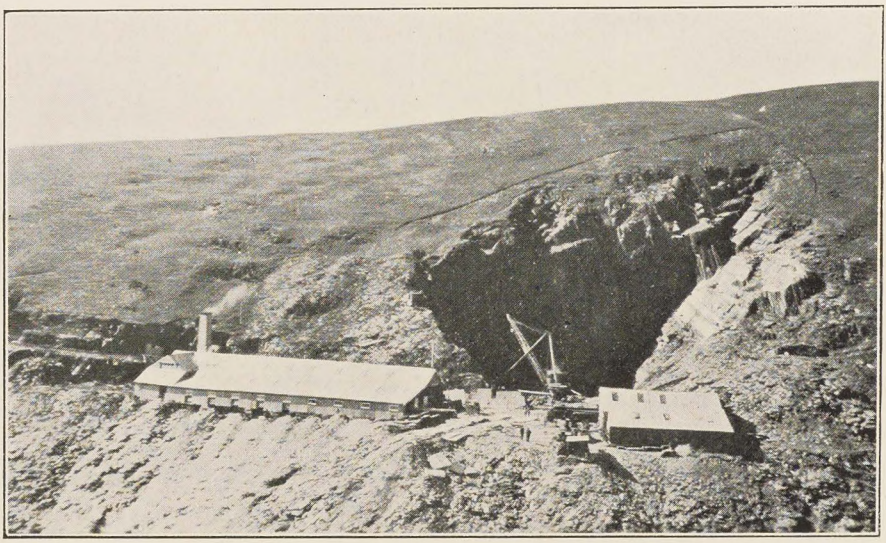
Sections 123 and 124, Hundred of Noarlunga.

(*Owner, G. Culver. Lessee, F. Edwards.*)

This quarry has been opened on the same or a slightly higher horizon than the Flagstaff quarry, on beds which dip 40° to W. 10° N. Mag. The quarry has a length of over 100yds., a width of 20yds., and ranges in depth from 10ft. to 40ft. The fracturing is similar to that of the Flagstaff quarry, but a considerable thickness of stone on the west is crumpled, and cannot be used for building. The quarrying has been unsystematic, owing to inter-



Tapley's Hill Calcareous Slate Quarry., Section 189, Hundred of Noarlunga.



Australian Slate Co.'s Quarry and Works, Section 756, Hundred of Noarlunga.

Tarlee Slate Quarry, Section 215, Hundred of Gilbert.

To face p. 21.]

mittent working, and development is hampered by piles of waste on the hanging wall and in the deeper portions of the quarry. The material has been used in some churches, but for the most part in private residences.

Section 78, Hundred of Noarlunga.

Two small quarries have been opened on this section on the western flank of the gully through which the main from Happy Valley reservoir to Adelaide is laid. The westward extension (down the dip) is stopped by the western boundary of the property. A maximum thickness of 50ft. of unworked ground separates these quarries from the eastern quarry on section 126.

The slate worked is dark-blue, thin-bedded, slightly calcareous, and, though lithologically identical, is below the bed worked in section 126. It dips at a slightly greater angle.

Section 126, Hundred of Noarlunga.

Just west of the above described quarries, in the space between the Main South Road and the eastern boundary of the section, is a large quarry, in which the slate dips 15° W.S.W.

The beds are true, showing very little development of crumpling. In addition to the cleavage at right angles to the bedding, there is a subsidiary cleavage crossing the other at an angle, and causing a slightly irregular or hackly fracture. Large, approximately rectangular blocks can be got out.

The upper portion of the quarry shows the effect of weathering, the stone showing buff color with the iron coloration developed along the bedding, cleavage, and joint planes. The deeper beds have been little affected, and for the most part are typical dark-grey slate color.

About a quarter of a mile west of this quarry, and about the centre of section 126, is a quarry benched out on the side of a gully for about 120ft. in length. The stone is similar to that seen in the other quarries, but the strike (N. 25° E.) and the dip (40° to W.N.W.) are extremely regular. The cleavage is 40° to E.S.E., and a cross system of joints, which are wide spaced, cross the bedding planes at an angle of about 70°. Very large stones can be got here when required, and the quarry seems to be reserved for this purpose. The joints are normally stained; the rock itself is blue-grey.

Section 189, Hundred of Noarlunga.

(Lessees, Dwyer & Warner.)

One mile to the westward of the last described quarry, on section 189, is a large quarry (250ft. by 200ft. by 40ft.) on the calcareous facies of the Tapley's Hill slate. The bedding planes continue visible, but the stone has no great tendency to split or cleave along them. The main bed of the quarry is 70ft. to 80ft. in thickness, and dips 40° to the west, with cleavage and cleavage joints at right angles to strike and dip. The thrust or cross joint system is also well developed.

All these systems are very regular, and the stone has a greater tendency to split along the cleavage planes at right angles to the bedding. In consequence of this feature the cleavage planes are regarded as the true beds on which to set the stones in building. The bedding or transverse joints are used as "facers."

The stone, when unweathered, is dark-grey slate in color, and is very uniformly banded with 30 to 40 layers per inch. Near the outcrop weather-

ing has resulted in a lighter colored or greyish slate. The quarry is in good shape for providing large supplies of this type of stone, which has been used in many private residences and public and semi-public buildings, among which may be mentioned the Roman Catholic church at Semaphore, and the additions now being made to Paringa Hall (now a school), which was built of this stone or stone of similar characteristics.

HUNDRED OF WILLUNGA, SECTION 756.

The Australian Slate Quarry Limited (*Vide* Rev. 14 and 31).

This quarry, situated on land, the mineral rights of which have been alienated from the Crown, has, with others in the vicinity, been worked for many years. Roofs stated to be 70 years of age exist in Willunga, and are in good condition.

The property, formerly known as the Bangor Quarry, was acquired in 1917 by Mr. J. Dunstan, and the Australian Slate Quarry Company, Limited, formed. Since then there has been a considerable extension of the quarry in depth, and a large increase in plant and productivity.

The quarry is a little over two miles by road south of Willunga, and at a considerable higher elevation. It is situated on the north-eastern slope of a deep ravine, and exposes portion of a wide belt of slate striking N. 25° E. and dipping 64° to E.S.E. The dip of this bed varies across its breadth, between about 64° and 72°. Small quarries and creek-bed exposures show similar slate to the eastward for a total width of more than a quarter of a mile, and other slate quarries such as Bastian's and Martin's prove the extension along the strike for over a mile. There is no lack of raw material for all time. The age of the bed is not definitely known, being either Lower Cambrian or Upper Pre-Cambrian.

The slate is for the most part thin bedded, and is cleaved along the bedding planes. The partings are somewhat variable, and the close cleaved slate is now used exclusively for roofing slate. At one time flagstones were split from these thin-bedded slates, and subsequent scaling of the flags brought them into disrepute. Now, however, only the thicker uncleaved layers, which occur at intervals in the thin-bedded slate, and which cannot be split for roofing slates, are reserved for flagging, hearthstones, and like uses. It is stated that there is no tendency to scale in the flags prepared from such layers.

A strong joint dips 55° W.N.W. from top to bottom of the quarry, and the beds have been broken down to this, so that it forms the eastern wall of the quarry. Good slate is present beneath this joint, which is one of a system of similar joints, some of which can be seen to the eastward.

There is a series of very thin joints that may or may not be filled with calcite and quartz, dipping about 50° to E.S.E., and which are locally known as "slides." They are specially pronounced over a zone of about 30ft. thick, and cause trouble by breaking up the big slabs, and may cause distortion of the bedding within a foot or so of each joint.

In addition to these there are "floors" or joints dipping about 15° to the westward at vertical intervals of 20ft. to 30ft., which are taken advantage of when possible in quarrying the slate.

In Martin's quarry (section 1008), to the northward, two parallel crush zones a few feet thick were noted, dipping 80° in a north-easterly direction. They appear to be structural fractures that may recur as the slate beds are followed along the strike, and though this type of fracture has not

been seen so far in the quarry of the Australian Slate Company, cross fractures may reasonably be expected at intervals. They are no detriment to working, but, on the contrary, if found, and utilised to form a face, would be of assistance.

A zone of a few feet in the western portion of the Australian Slate Quarry is spoilt by interbedded quartz calcite veins, but they die out to a very great extent near the bottom of the quarry. About 50ft. east is a zone 5ft. to 8ft. wide, in which the bedding is somewhat irregular, and from which the stone has to be rejected. The balance of the bottom of the quarry of 60ft. total width is almost all thin bedded, and fit for slates. The odd layers of thick slate are utilised for flags. To the eastward of the bottom, some distance up the eastern side, is another belt that is said to yield flagging of good quality. The quarry has a width at the top of over 200ft. at the face, and a width at the bottom of 60ft. It has been benched into the hill, but the floor for 60ft. back from the face has been carried to a depth of 40ft. to 45ft. below the level of the bench, that is, to nearly 200ft. below the top of the face. Extension is taking place to the westward and in depth.

Future work will probably take the form of removing 20ft. to 40ft. of the top slate as waste, N.N.E. of the face, and then quarrying the underlying prism of slate.

On the southern side of the ravine stripping has revealed good quality roofing slate and a convenient "flat floor" to break to, and this locality, when opened and provided with transport, will provide a face additional to the main quarry.

The slate is a very uniform greyish-blue color, and, judging from the old buildings in the district, fades very little and very uniformly. A little pyrite may occasionally be seen, but it is confined to cleavage planes, and is not important. Lime is present in the slate, and in this connection the second analysis on page 24, of material chipped from the trimming of the slates in August, 1922, may be compared with the first analysis, quoted by the Chief Inspector of Mines in 1919, of slate that came from a slightly higher level.

Cleavage is parallel, coincident with the bedding planes, and the slate cleaves readily. The fracture varies somewhat; some is exceedingly smooth, others show a very slight undulatory surface—probably more apparent owing to the reflection of light than in actual measurement, and some breaks to rather rough surfaces. The roofing slates, as stacked, average one-quarter of an inch in thickness, and the standard sizes are:—14in. x 8in.; 16in. x 8in., x 9in., and x 10in.; 18in. x 9in. and x 10in.; 20in. x 10in., x 11in., and x 12in.; 22in. x 11in. and x 12in.; 24in. x 12in. and x 14in. Other sizes are made to order.

The following details regarding the analysis and testing of some samples of roofing slate from the Australian Slate Quarry are taken from *Architecture*, August 20th, 1919, being portion of an article on the Adelaide (Willunga) slate, written by Mr. John Dunstan, one of the proprietors of the quarry.

The specimens of Adelaide slate referred to are understood to be specimens taken by a visiting architect from the Australian Slate Quarry, at a depth of about 100ft. from the surface. They would therefore represent the best quality obtainable, and should be free from the influence of weathering.

An analysis of one of these samples by Mr. W. S. Chapman, of the School of Mines, is shown in the first column; the second sample was taken by the writer in 1922.

	Per cent.	Per cent.
Silica (SiO_2)	53.64	52.86
Alumina (Al_2O_3)	14.90	13.78
Ferric oxide (Fe_2O_3)	0.64	0.72
Ferrous oxide (FeO)	4.87	4.51
Magnesia (MgO)	4.60	4.58
Lime (CaO)	6.46	7.36
Soda (Na_2O)	1.06	1.42
Potash (K_2O)	3.02	2.75
Water at 100° C.	0.14	0.16
Water at above 100° C.	4.65	3.12
Carbon dioxide (CO_2)	4.75	7.79
Titanic dioxide (TiO_2)	0.75	0.79
Phosphoric anhydride (P_2O_5)	0.37	0.17
Sulphur trioxide (SO_3)	nil.	—
Chlorine (Cl)	—	0.01
Ferric disulphide (FeS_2)	0.54	0.28
Manganous oxide (MnO)	0.06	0.05
Barium oxide (BaO)	—	nil.
Carbon	—	present
	100.45	100.35

A statement is also given in the same article of the particulars of a test made by Professor Warren, of the Engineering School of the Sydney University, on the Adelaide slate, and also on slate stated to be best purple Bangor slate. The particulars are as follows:—

P. N. Russell, Engineering Laboratory, University of Sydney.

Test—Slate—Crossbreaking and Hardness.

Nature of Specimen.	Span. l	Width b	Thickness. d	Load in lbs. Central W.	Modulus of Rupture pounds per sq. inch.	Resistance to punching under drop hammer inch-lbs.	Brinell hardness.	Relative hardness.
	Inch.	Inch.	Inch.					
Adelaide Slate ..	12	9	0·18	160	9876	80	122	1·0
" " ..	12	9	0·16	135	10547	80	119	0·97
" " ..	12	9	0·21	230	10430	60	101	0·82
" " ..	12	9	0·21	232	10521	60	92	0·75
Best Purple Bangor Slate	12	9	0·15	130	11556	60	114	0·93
	12	9	0·16	135	10546	68	88	0·72

It is remarked that the tests of the Bangor slates (which are understood to be imported slates) were for comparative purposes only.

The load on the Brinell machine was 500 kilogrammes for one minute.

The formula for the modulus of rupture is:—

$$f = \frac{3wl}{2bd^2}$$

The amount of carbonate of lime present in the slate, as shown by the foregoing analyses, is high.

The high lime content suggests that the acid atmosphere of coal-burning cities will have a prejudicial effect on the slates, but the general dryness of the Australian climate will do much to offset this. The strength is

shown by the foregoing tests to be satisfactory, as the average modulus of rupture of nine varieties of American slates* was shown by Professor Mansfield Merriman, of Leigh University, to average 8,698lbs. per square inch, over 33 specimens, while the average modulus of rupture of the four specimens tested above is 10,343lbs.

Jack-hammer drills or chisels are used in the quarry to break a slab free at its end or bottom. It is then wedged out and hoisted by a crane of five tons capacity on to a trolly (waste is hoisted in a box and dumped).

The thick and heavy slabs are then broken into convenient sizes and thicknesses for the splitters. The stone is said to split more easily after a few days' exposure, but in practice it is worked up very soon after leaving the quarry. The slabs are taken to the dressing shed, split to thickness, and machine trimmed to size.

The dressing shed is substantially built of slate pannelling on timber framework, and is lit from above. It houses a number of trimming machines, a water tube boiler, engine and air compressor, while a number of saws is being installed. A well-equipped repair shop completes the plant.

The slates are finding increasing application in the Victorian and New South Wales public works and railways, and in private architectural work in those States and in Adelaide. Between 2,000 and 3,000 slates a day are produced at present.

Founded on the utilisation of slate panels in house construction in the United States, an interesting use has been made of slate at the works. Panels of flagging ½in. to 1in. thick are suitably supported by timber framing to form cavity walls, partitions, and ceilings. A house with an outer shell of brick is being built in Willunga on this principle, the panels being held into wooden studs by beading. A considerable saving of time and expense in building is thus effected. In place of wood, T iron and reinforced concrete beams and studs may be used, the slate flags being cemented into the framework as if they were panes of glass. The experiment is of interest as a possible source of very considerable expansion in the slate-flagging industry.

Hundred of Willunga, Section 1008.

Martin's Quarry.

This quarry has not been worked for a considerable time, and has been damaged by injudicious disposal of waste. From the extent of the workings they must have been of considerable importance, producing both slate and flagging, which was shipped from Port Willunga, the bulk of the product going to Melbourne. The quarries, which are situated at the confluence of two gullies on the right bank of Belltunga Gully, expose slate striking N. 30° E., and dipping 70° to the eastward. The south-western quarry shows a crush zone at right angles to the strike. Two joint systems, one dipping 80° N.E. and the other 30° S.W., are visible. This opening is almost wholly filled with waste rock, but is stated to have been 100ft. in depth. About 100 yards to the north-north-east this bed is stated to have been worked to a depth of 70ft., but rubbish has accumulated in the pit from the breaking down of 30ft. to 40ft. of poor-quality slate to the north. This poor material overlies the good stone.

The ridge between the two confluent tributaries has been worked from either side, but the chief working is on the southern tributary, where a quarry (the east section of the first described) shows a 40ft. face, and is said to have been filled to a considerable depth. Flatly dipping floors

* Bull. 586, U.S.G.S.

occur at intervals of 20ft. to 40ft., and were taken advantage of in working. Really good stone only came in beneath the second flat floor, say, 30ft. in depth from the surface.

A distinct quarry near the top of the ridge and to the south-east has exposed good-quality thick-bedded slate, which was utilised for bordering and flagging.

There is obviously a very large bed of slate to be worked, but a considerable amount of work would have to be done to make the faces of good stone available.

S. Bastian's Quarry.

About 300 yards to the south-west of Martin's quarry is a quarry, at one time worked by S. Bastian, on either side of the Belltunga Creek, which flows through the quarry. The quarry is of fair size, and exposes somewhat inferior slate striking N. 20° E., and dipping 70° into the eastern side. The best stone is on the east side of the quarry, but the overhang of the slate and overburden caused trouble in working in that direction. The eastern side appears to be only up to the bed touched in the westernmost workings of Martin's quarry.

The western face is higher, but owing to the slopes of the gully there is little stone that has been far removed from the surface, and this accounts for the poorer quality of the slate and the abnormal proportion of waste. The principal product was roofing slate.

COUNTY OF LIGHT.

Hundred of Gilbert, Sections 215 and 294.

Tarlee Bluestone.

These two sections, about a mile and a half west of Tarlee, contain quarries that in the past have furnished stone for many of the buildings in the vicinity, for a number of the railway stations, including portion of the Adelaide station, for the Islington railway workshops, and for the base courses of the older portion of the Adelaide Museum.

The rock is a thin-bedded clay slate merging into argillaceous sandstone, and lies nearly horizontally, about 10° being the maximum dip. A slight amount of folding has taken place along N.N.E. to S.S.W. axes, and there is a tendency for these axes to pitch to the north. The quarries have been opened near the crests of the anticlines, and are very shallow.

The stone when unweathered is bluish-grey, and the weathered material a lighter grey with iron stains on the joint planes. It breaks readily along the bedding planes and to joints, and can be readily dressed. A favorite dressing is to incise narrow, roughly parallel grooves along the bedding planes of the exposed faces.

There are considerable differences in texture and degree of decomposition in the different beds, and some of them fret badly, and should be rejected. The base course of the old portion of the Adelaide Museum is a case in point. The limit of depth in some cases appears to be determined by the increasing hardness of the stone.

Section 215.

McInerney's Quarry.

This quarry, to the north of Hill's section, has been the largest supplier of this type of stone in the district.

A small southern pit exposes hard, undecomposed slate dipping 10° to N.E. The stone breaks to bedding planes, but indifferently at right angles

to the bedding. It has been too hard for general use in building, but large blocks were taken from here for the foundations of the G.P.O., Adelaide. These are now being removed during the reconstruction of the post office and are very sound.

The main quarry, adjoining, on an upper bed covers an irregular area of 100yds. x 100yds. There is about 10ft. of overburden and 15ft. to 20ft. of stone. The bulk has been removed for buildings and the waste for roads. The stone is "milder" than in the south quarry, but does not fret away as a general rule. There is a belt of crumpled stone about 20ft. wide running N.W. to S.E., and probably identical with that seen in Hill's middle quarry (section 294). But for this the beds are undisturbed.

From this quarry was taken the stone for, among others, Islington workshops, Adelaide, Stockport, Tarlee, and Saddleworth stations, and the Linwood road bridge. Available supplies appear to be very large should this class of stone be desired. Weathering governs the depth to which the quarries are taken, the undecomposed blue slate being regarded as too hard for general use. On the other hand, some of the beds near the surface are so decomposed that there is a tendency for the stone to fret away, and this stone should be rejected. The soft or grey stone in Adelaide powders and exfoliates and rubs and blows away. Only the denser of this stone should be used.

Section 294.

Hill's.

The easternmost quarry is about 120ft. x 100ft. x up to 20ft. deep. Overburden, 5ft. to 10ft., has had to be removed. The quarry is on an anticline the east leg dipping about 5°. The stone is thin-bedded, with major bedding planes 6in. to 2ft. apart. It is fissile and cuts well across the bedding. Some is very soft and frets badly. The road bridges at Underdale and Hamley Bridge are stated to be built of material from this quarry.

A hundred yards to the west is the middle quarry of section 294, on another and similar anticline. The stone is harder and darker. The quarry is somewhat irregular, 120ft. x 120ft. x 10ft. to 20ft. deep, including 5ft. to 10ft. of stripping, and provided stone for Tarlee houses and the Islington workshops. There is a small crush zone, trending N.W. to S.E., in this quarry.

About 100yds. to the west is the third quarry, a small opening, on stone dipping 7° N., and intermediate in hardness between the eastern and middle quarries.

COUNTY OF STANLEY.

Section 39 (part of), Hundred of Clare.

Pink's Quarries.

The town of Clare is built almost entirely of slate obtained from a line of quarries within a few hundred yards of the centre of the town.

The bed worked is a thick-bedded siliceous slate exposed in the north quarry for a width of 140ft. The strike is N.N.W. to S.S.E., and the dip is 85° W.S.W. There are four systems of joints in the beds exposed:—(1) Vertical across the strike; (2) dipping 35° E.N.E.; (3) 50° S.S.E. and (4) 50° N.N.W. In consequence the stone breaks into blocks a yard across as a maximum. The vertical transverse joints, the west dipping joints, and the east dipping joints are utilised in quarrying.

The slate in the deepest portions of the quarries is hard and of a greyish-blue color. It is siliceous, and contains a little mica. The stone used, however, is almost invariably more or less decomposed, and ranges in color from

grey through brownish-grey to buff. Some examples of its use are to be seen in which the iron-stained joint planes are used as facers, but for the most part the grey stone is used either in the rough or with the face chisel-dressed. The general effect is good, and there is no doubt that the stone used in Clare is fairly satisfactory in resisting the effects of weathering. It is affected by salt damp.

About half a mile south of the railway station along the main road, and half a mile west of the latter, are two quarries, Donnellan's and Beame's. They are shallow, and the stone is more weathered than the stone of Pink's quarry, but there is no doubt but that they are on the same bed, which strikes N. 20° W. This stone has also found its use in Clare.

HUNDRED OF CLARE, SECTIONS 307 AND 178.

Mintaro Slate.

The full and complete report of the Government Geologist, published in Review of Mining Operations, No. 20, pp. 25-30, is reprinted, as the writer found only the minor changes, recorded below, due to eight years' work since the Government Geologist's report.

Report by the Government Geologist (L. Keith Ward, B.A., B.E.).

Acting under instructions from the Honorable the Minister of Mines, the writer visited the Mintaro Quarries on February 10th, 11th, and 12th, 1914. The following report embodies the observations made during that visit:—

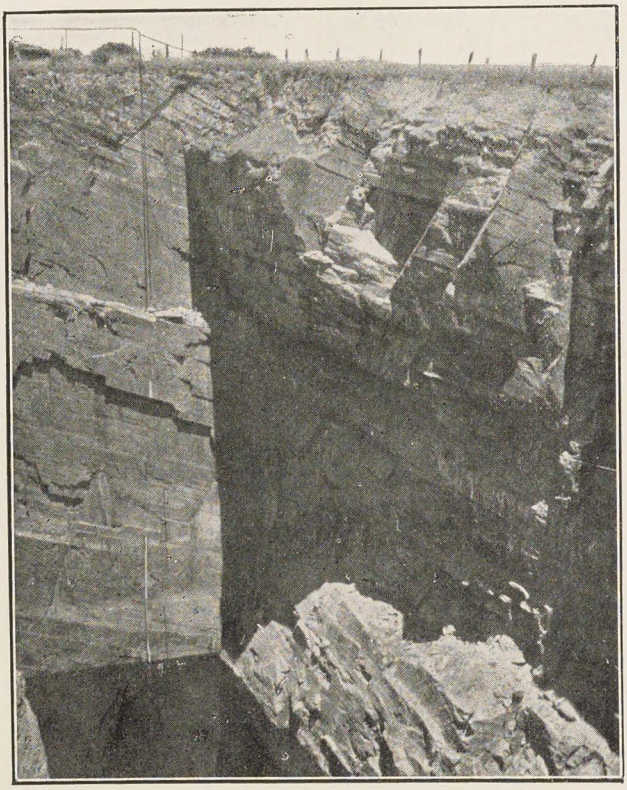
The flagstone quarries are situated in the S.E. corner of the hundred of Clare, at a distance of about a mile to the W. of the township of Mintaro and 5½ miles to the W. of the Mintaro Railway Station. The flagstones are carried to the railway line by horse teams. The Mintaro Railway Station is distant 82¾ miles from Adelaide.

Quarries are at the present time being worked by the Mintaro Slate and Flagstone Co., Limited, and by Mr. W. Laycock. The company's quarries are located in sections 307 and 178 of the hundred of Clare, and Mr. Laycock's quarry in section 344 of that hundred. Both properties are freehold.

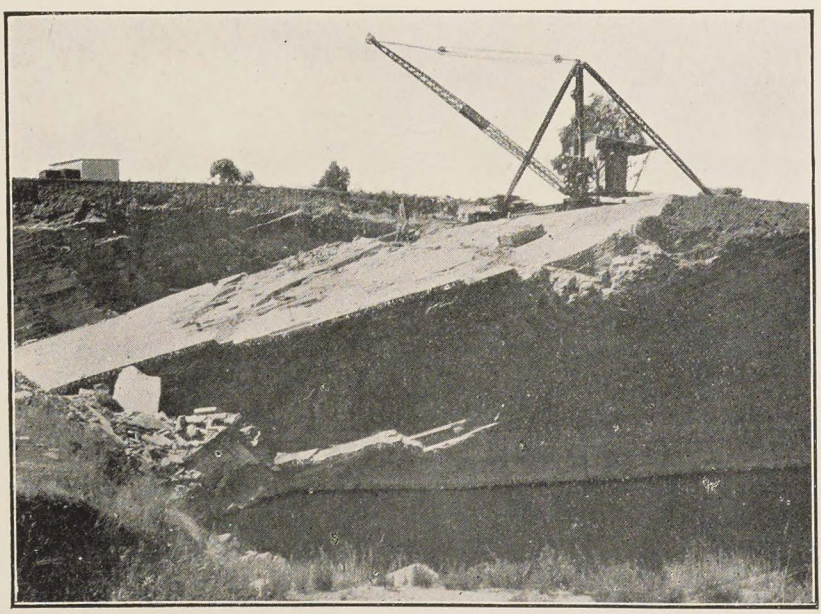
The quarries are situated on the lower slopes of a low range which constitutes the W. boundary of a broad valley traversed by the Northern railway line.

The rocks in the area with which this report is concerned are wholly slates, which are of Cambrian age, and which dip to the W. at angles of 22° and 27°. The slate formation is of great thickness, and is overlain on the W. by massive quartzite.

The slate from which the flagstones are obtained is a dense textured rock of a bluish-grey color and remarkably even grain. A few rounded pebbles of quartzite have been found during the work of quarrying embedded in the slate, and where these occur the bedding planes are noticeably disturbed. These pebbles are in all probability ice-borne boulders which have been dropped by floating ice during the period of sedimentation—a supposition which is supported by the outcrops of typical till on the main road between Mintaro and Clare, at a distance of 3½ miles from Mintaro. But for these very rare boulders the Mintaro slate is nearly homogeneous. The



Mintaro Slate and Flagstone Co.'s No. 2 Quarry (1914).



Mintaro Slate and Flagstone Co.'s No. 3 Quarry and No. 1 Quarry (full of water, 1914).

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bedding planes are to be recognised in most parts of the formation rather by slight differences in color than by changes in texture of successive beds.

The unweathered slate contains a small proportion of iron pyrites, usually in the form of disseminated crystals in certain beds of the formation. The amount of this pyrites is, however, not large, and the cleavage planes of unweathered stone rarely show any exposed pyrites. Where weathering has occurred there are stains of limonite, and in some places stellate aggregates of tabular marcasite crystals on cleavage surfaces. These are purely superficial, and may be removed by rubbing the face of the stone.

Some of the slate obtained from shallow depths is more deeply stained with limonite, doubtless from the decomposition of pyrite, and being worthless for flagstone, is rejected as waste.

There are in some places narrow veinlets containing quartz, calcite, and sporadic crystals of pyrites traversing the unweathered slate, the fissility of which is unaffected by their presence. The presence of the veins does, however, cause a small rib to appear on the cleavage surfaces, but is not regarded as a detriment to the few flags in which such veins occur. These veinlets, which are locally known as "seams," are inclined to the bedding-planes at angles other than right angles.

The final result of the weathering of the slate is a reddish soil, in which a little white travertine limestone occurs. Beneath the soil, which is from 1ft. to 3ft. in depth, there are in most places several feet of friable slate which gradually becomes more and more compact. The quarries of the Mintaro Slate and Flagstone Company are situated on beds, the dip of which is 22°, and these beds weather in such a manner that no residual blocks of stone remain in the surface soil; but the more steeply inclined beds to the E. weather to a soil in which large fragments of undisintegrated rock occur. The depth of weathering is rather variable. The stone occurring in the Mintaro Slate and Flagstone Company's quarries at a less depth below the surface than 25ft. is regarded as overburden, and is totally rejected. Between depths of 25ft. and 40ft. the weathered stone is culled out and thrown away, and below 40ft. the waste due to the influence of weathering is almost negligible. The exposure at Mr. Laycock's quarry is not yet sufficiently extensive to fully determine the depth of weathering and its effect on the character of the stone. The flagstones obtained from this quarry have been won from relatively shallow depths, and there are no exposures of unweathered stone with which to compare them.

The divisional planes, whether actual or potential, which are present in the slate beds, and which determine its suitability for working, are the results of earth movements since the Cambrian epoch. These divisional planes are only fully revealed by extensive workings, and for this reason it is always a matter of difficulty to determine the commercial value of the slate beds during the earlier stages of prospecting.

The cleavage of the slate follows the bedding planes, and the positions of the planes along which the slabs of slate will cleave are marked by dark-colored bands which are only visible on close inspection. The spacing of these cleavage planes—at intervals of rarely less than an inch—is such that flagstones fashioned from the stone are free from danger of scaling. The cleavage surfaces are on the whole remarkably smooth and even, but on some faces there are small wrinkles known as "feather marks," which have no constant orientation. These markings are not serious blemishes in the flagstones.

The joint planes, which cut across the bedding planes of the belt of slate worked by the Mintaro Slate and Flagstone Company, are for the most part to be grouped into two series—

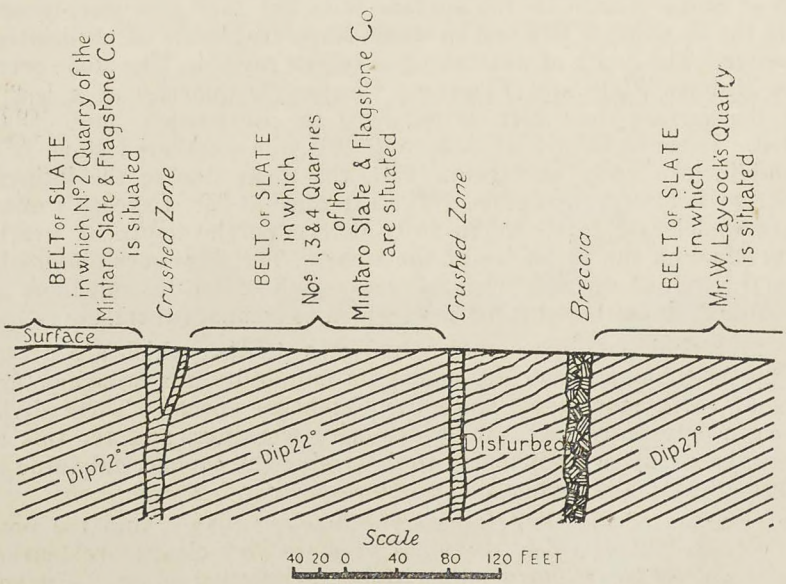
(1) A meridional series, the strike of which is within a few degrees of the magnetic meridian;

(2) A series the strike of which varies between the bearings N. 67° W. and N. 86° W.

The major joint planes in these quarries are continuous from the surface to the lowest level of the workings, and are practically vertical. Parallel to them and near the main joints are similar joint planes, which traverse some of the beds, and do not extend continuously for any considerable vertical distance. In addition, there are subsidiary joints, irregularly oriented, at some places where the main N.-S. and E.-W. joints intersect. These, however, do not as a rule penetrate far into the beds.

The "grain" of the slate in these quarries runs in a meriodional direction, and is utilised in the work of quarrying, but the stone is stated to be of practically equal strength, both with and across the grain.

The stone raised from shallow depths can readily be split as soon as it is quarried, but the more deeply seated stone must be stacked on its edge for some months before the best possible results can be obtained from it. Slabs from a depth of 120ft. from the surface may require seasoning for a period of 12 months. For this reason it is necessary for the company to carry large stocks of slate in the yards. Unseasoned stone is not sent away from Mintaro.



Section showing Belts of Slate at Mintaro, looking North.

The principal quarries are situated on a belt of slate which has a total width of not less than 300ft., and which has been partly proved for a length of over 15 chains.

This belt may extend to the W. beyond the W. wall of the No. 2 quarry, but there are no exposures that may serve to indicate how much greater is the workable width in that direction. The No. 2 quarry is situated on the W. part of the belt which has not been worked elsewhere. It has a maximum width of 100ft., and is bounded on the E. by a vertical zone of crumpled slate, 10ft. to 15ft. in width. This disturbed zone runs from the surface to the bottom of No. 2 quarry. Its strike is meridional, and it constitutes the E. wall of the quarry. Near the S. end of the opening it is a simple break, but, as work proceeded N., it was found to bifurcate, the slate between the two branches being somewhat disturbed also.

This zone of disturbance is probably identical with that which forms the W. wall of No. 3 quarry to the S. To the E. of the break the slate possesses the same strike and dip as in No. 2 quarry, and on this E. portion of the belt are located No. 1 and No. 3 quarries. The full width of workable slate in these quarries is 200ft. This latter body of workable stone is bounded on the E. by a crushed zone approximately parallel to that mentioned above.

Still farther to the E., at a distance of 81ft. from the E. zone of disturbance, is situated a fault breccia which marks the E. limit of the slate which possesses a dip of 22°. The slate to the E. of the breccia where exposed in a creek bed in section 178, hundred of Clare, and also in Mr. Laycock's quarry, has a dip of 27°, also to the W.

The outstanding structural feature of the belt of productive slate worked by the Mintaro Slate and Flagstone Company is the remarkable constancy of its dip at 22°, in spite of the well-defined zones of dislocation which traverse it.

The Company's Quarries.

(1) The Mintaro Slate and Flagstone Company, Limited, possesses a block of land, the total area of which is a little over 60 acres. There are three quarries in the property, only one of which (No. 3) is now being worked.

The flagstones were first found outcropping in the bed of a creek which runs through section 178 of the hundred of Clare, over 50 years ago, and some of the slate was exhibited in London in 1861. The No. 1 quarry (also known as Priest's Quarry) was the first worked, being adjacent to the site of the original discovery.

This quarry is said to be 80ft. deep, and occupies an area of approximately 2,000 square yards. It is now full of water, which is used in the dressing plant.

The No. 2 quarry is a much larger excavation, the area covered being about 7,000 square yards, and the deepest part being 130ft. below the surface. This quarry is situated to the N. of the road traversing the property, and from it the greater part of the flagstone marketed has been obtained. The workings do not extend in a W. direction for the full width of the workable slate. Nor have the quarry benches been carried to the limits of the valuable stone in either a N. or S. direction. To the E. of the crushed zone which forms the E. wall of the quarry, lies the belt of slate which is worked in the No. 1 and No. 3 quarries. No work is at present being carried on in No. 2 quarry, for the reason that the face was found to be too narrow to supply the increasing demand for the flagstone, and it was considered better policy to open up a fresh quarry with a greater width of working face.

The No. 3 quarry was started with this object, and will provide a face having a horizontal width of 200ft., or a width of 217ft. measured in the plane of the beds. At the present time this quarry, which is immediately to the N. of that which was first opened up, is producing some slate, but no small part of the quarrying operations are still concerned with the stripping of overburden. The angle of dip of the slate is such that when one of the beds is continuously exposed for the whole workable width the depth of the quarry will be at least 80ft. on the W. wall.

The probable reserves of unworked stone within the limits of the company's property are enormous, and may be expected to extend far beyond the limits of the present openings, which occupy but a small fraction of the area comprised in the property.

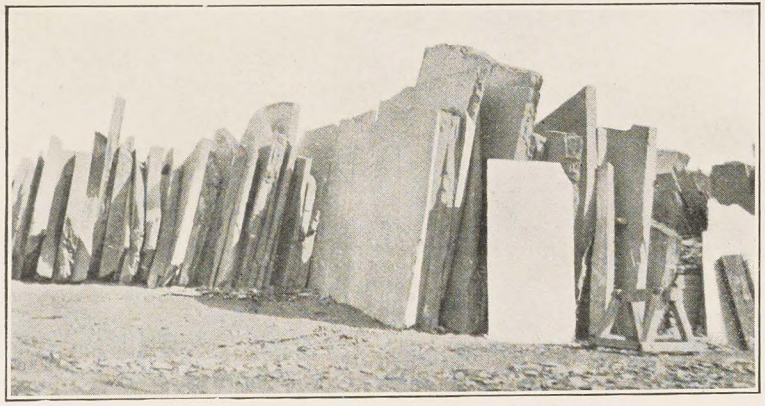
All the mining and splitting are done by hand labor. In plugging the slate, steel plugs and iron feathers are used. The plugs are driven from 6in. to 1ft., but no deeper, for the reason that the slate tends to break with a bevel edge rather than at right angles to the bedding planes if deep holes are used. The No. 3 quarry is equipped with a steam crane of 10 tons capacity for hauling the flags from the quarry, and a handpower crane of 5 tons capacity for loading the trollies. The No. 2 quarry is equipped with a steam crane of 7 tons capacity, and a handpower crane capable of lifting 2 tons for loading the wagons that carry the slate to the railway. The stone exported from the State is sent away with hammer-dressed edges, but most of the flagstones, &c., sold in South Australia are dressed in the company's yards at Mintaro. Two Allan oil engines of 22-H.P. each supply the power. One engine drives two sets of eight saws each and the carborundum rubbing cylinder. The other engine drives two sets of eight saws each and a planing machine, and to this unit a table rubbing machine will shortly be added. The saws used are of 10-gauge mild steel plate, 10in. wide, and from 9ft. to 14ft. in length. Sand obtained from Glenelg is the abrasive supplied to the saws.

The planing machine is a single-acting machine with a bed 3ft. 6in. wide and a travel of 14ft. It is used for "nosing" (*i.e.*, rounding the edges off) the slate, and is found capable of nosing 210ft. in a day, whereas one man by hand labor can nose from 35ft. to 40ft. in a day.

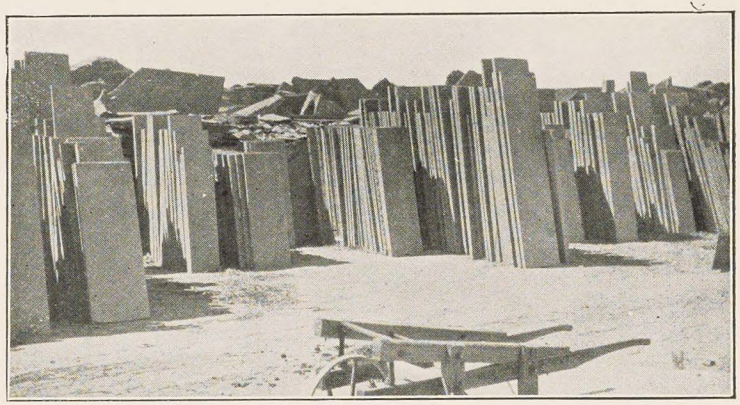
It is the object of the company to carry as large stocks of slate as possible—a necessary provision in view of the increasing demand for the slate. At the stocktaking on December 31st, 1913, it was estimated that the stocks held at Mintaro were then 50,000 square feet of slate 2in. thick, and 65,000 square feet of slate 1½in. thick. In the framing of this estimate all sizes of unworked stone have been expressed in the thicknesses mentioned. In addition, it is estimated that 700 tons of flagstone were at the time in stock in the Melbourne yards belonging to the company.

The sizes of large flagstones sent out are limited by the dimensions of standard trucks, and no flagstones measuring more than 14ft. 6in. by 7ft. 6in. are dispatched by rail, although larger ones can be supplied by the quarry. The thicknesses most in demand are 1½in. and 2in., but the company quotes prices for flagging of all thicknesses between 1in. and 3in.

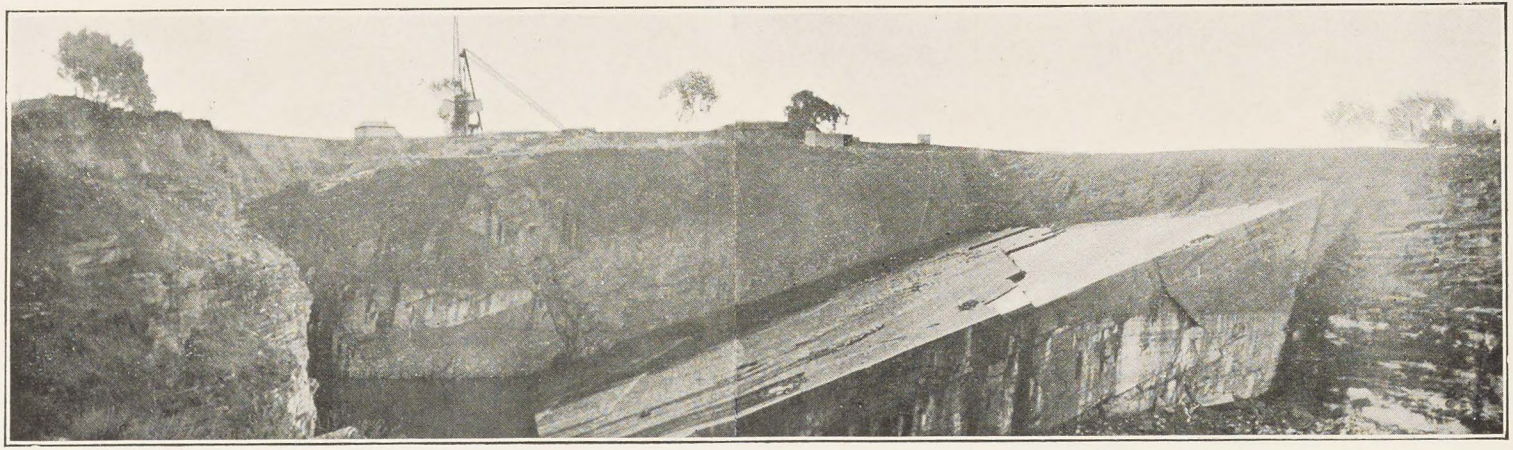
The smallest stock size is that which is used for grave kerbing, the dimensions being 3ft. 6in. by 7in. in width. Small sizes have been employed in special work, but there is at the present time no regular demand for them. The uses to which the slate is put are manifold, the principal



Slate as Raised, Seasoning prior to Splitting.



Prepared Slate Slabs.



Looking North over Nos. 1 and 3 to No. 4 Quarry (1922)—Mintaro Slate and Flagstone Co., Hundred of Clare.

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articles manufactured being hearths, sills, steps, kerbing stones, shelves, cricket pitches, troughs, tanks, vats, billiard table tops, ledgers and vault covers, slabs for lavatories, paving flags, and switchboards.

As in all quarries in which slate is worked, there is inevitably a considerable amount of waste material produced. The upper part of the slate bed is so affected by weathering that it is of no value whatever; but there is some unavoidable waste of unweathered material, and it should be the first object of the company to ascertain the percentage of waste at each stage of mining and dressing operations.

The Mintaro Slate and Flagging Company has hitherto found its best market in Melbourne, and it is now taking steps to open up a branch in Sydney.

Tests were made on the slate from these quarries in March, 1891, in the engineering laboratory of the University of Melbourne by Professor W. C. Kernot, with the following results:—

Description.	Span.	Breadth.	Depth.	Breaking Load.	Ultimate Deflection.	Remarks.
1. Beam of Mintaro slate	36″	9·84″	2·08″	1,935lbs.	·05″	Clean uniform fracture
2. Portion of No. 1 slate	18″	9·84″	2·08″	4,270lbs.	·03″	"
3. Other portion of No. 1	18″	9·80″	2·07″	4,575lbs.	·03″	"

The value of the flagging produced annually from the quarries of the Mintaro Slate and Flagstone Company has shown a steady increase, and during the year 1913 amounted to over £7,000. The total value of the flagstones produced since July, 1893, is £64,443.

The flagstones from these quarries have been extensively used for street paving, and have given entire satisfaction wherever they have been employed. The Town Clerk of Adelaide advises that the wear of the city footpaths paved with Mintaro flagging has been ½in. in 14 years, this measurement having been made at a distance of 3ft. from the building line, where the pedestrian traffic has been the heaviest.

This flagging is specified wherever such material is required in Government buildings in South Australia.

Mr. W. Laycock's Quarry.

This quarry was first opened up about two years ago in the hope of locating another deposit of workable flagstone. The quarry is situated to the E. of the belt in which the Mintaro State and Flagstone Company's quarries are located, and the beds of slate exposed in it dip to the W. at 27°.

While a considerable amount of work has been done, and a maximum depth of 50ft. has been reached, it cannot be said that the existing excavation is a conclusive test of the country lying to the E. of the main productive belt. The steeper dip of the slate in this quarry is in no way a mark of inferiority of the material. Of much greater importance is the determination of the value of the flagging are the nature of the cleavage surfaces and the disposition of the joints. In the past there has been some irregularity in the cleavage surfaces and the main joints have been spaced

at rather narrow intervals, but these phenomena may prove local if more extensive workings are opened up. The main joints have a strike bearing N. 28° E. and dip to the S.E. at 52°.

The greater part of the flagging hitherto quarried has been won from shallow depths, and exhibits the same properties as the upper part of the slate in the larger quarries to the W. The best stone obtained comes from no more than 15ft. beneath the surface, and these beds are not exposed in depth, being stratigraphically below those seen at the deepest part of the quarry.

Some 70 tons of slate have been sent to Adelaide, where the work of dressing has been carried out. The largest flags obtained measure 10ft. by 3ft., and are 7in. thick. The quarry is equipped with a hand-power crane of 2 tons capacity.

This attempt to prove the value of the slate in this locality, although so far not entirely successful, has not been carried far enough to determine the economic prospects of the locality in which the quarry is situated. (10-3-14.)

The No. 2 quarry (page 31) is no longer in use, as (1) the area at the bottom was somewhat constricted; (2) there was a tendency to develop jointing, especially at the north end (the south end is blocked by a road); (3) the deeper stone was too hard for many purposes. The very dense deep-level stone is much desired for flagging, but it is not in demand for purposes for which holes have to be drilled in the slabs. The deep stone also requires a long period of seasoning to enable it to be split truly without "running off" the plane of separation. Some of the blocks that have been seasoning for 12 years are only now being split.

Speaking generally of the quarries, it is found that the deepest stone is the hardest, and that it requires the longest period of seasoning before splitting. A stone that contains its quarry water, or even one that has been wet by rainfall or soakage from the ground, is very liable to split badly. Splitting is most effectively done in the summer.

The No. 3 quarry, contiguous to the deep hole known as No. 1 quarry, has been deepened very considerably and worked back to the eastern crush zone, and down it to a depth of 20ft. to 30ft., and as far as the western crush zone. There is a very large supply of proven stone under foot, but it was becoming too dense for such markets as preferred a "mild" slate, and a further area has been stripped to the north of and adjoining No. 3 for a length of 120ft. along the strike. The western crush zone is exposed, and "mild" slate is being got immediately to the east of it. Slates are being taken from this and No. 3 as thin as $\frac{1}{2}$in.

At the dressing plant the two oil engines referred to in the Government Geologist's report have been superseded by an 85 h.p. gas engine, fed by a gas producer using coke and charcoal. Two large rubbing tables have been added to the plant, so that more work can be finished off here.

The slate (flagstones) is of very high quality, and if chosen with due regard to its use has proved most satisfactory. The slabs are produced in thicknesses of $\frac{1}{2}$in. to 3in. by $\frac{1}{4}$in. gradations.

At the end of 1921 the total material seasoning in the yards and in stock at the depots was valued at £12,000.

The total sales of slates from the quarries from 1893 to December, 1921, are £110,300, and the output of flagging from 1914 to 1922 amounted to 1,200,000 sq. ft. It is probable that the total output exceeds 3,000,000 sq. ft. from the inception of the quarry.

Hundred of Clare, Section 344.

W. Laycock's Quarry.

The quarry was closed down shortly after it was seen by the Government Geologist. It was stated that the joints were too numerous, and that the slate did not split as cleanly as the Mintaro slate.

Section 216, Hundred of Upper Wakefield.

Auburn Slate Quarry (B. I. Mellor).

A thin-bedded slate, which is probably a portion of the "Tapley's Hill series" developed near Adelaide and at Tarlee, has been worked in a quarry about 90ft. x 150ft. by 0-45ft. deep. From this excavation has been taken the stone for the town of Auburn, the wall at the front of the Art Gallery the base courses of the School of Mines, Adelaide, and the foundation courses of Wilkinson's building in Grenfell Street, and of the Hindmarsh gas-works. It may be noted that when these buildings were erected the stone had to be carted 10 miles to Saddleworth railway station. Now the nearest station is within 1½ miles from the quarry. The beds dip to the N.W. 15° and are very regular, but the quarry is opened in a northerly direction to take advantage of the jointing, one system of which dips 80° to the east and the other 80° to the north. They are no detriment, as stones up to 20ft. long have been obtained, a length far beyond that required or desirable.

The stone exhibits the thin-bedding characteristic of the slates of Tapley's Hill, but whereas the latter splits more easily on its cleavage than on the bedding planes, it is along the bedding planes that the Auburn slate splits. Thus Auburn slate should be built into a wall on its bedding, but the Tapley's Hill slate is built on the cleavage planes.

The Auburn stone is grey in color when fresh, but there are lighter colored bandings of semi-weathered material alternating with the darker bands. The stone breaks to the joints, and there is a "rift" parallel to the N. and S. jointing, along which the stone also breaks truly; the E.-W. break is much more irregular, and only the ends of blocks are broken in this direction.

The stone is used either with the natural-breaking surface smoothed, or scored with a narrow chisel along the line of the bedding planes. It stands the weather well, but two beds of hard slate containing layers of scattered limonitic aggregates were pointed out to the writer as being liable to fret to a slight extent. The softer, normal, and even-bedded material seems to be free of this defect; but the much weathered and lightest colored stone exfoliates badly.

The east wall of the quarry is formed by a small quartz vein in one of the joints, and there was no exposure to show if the stone improves beyond it. The nature of the bed and the north and west walls indicate that there should be very abundant supplies of this stone, and the building of the Clare line has considerably altered the transportation factor.

LIMESTONE AND MARBLE.

Travertine.

No discussion of the building stones of South Australia would be complete without mention being made of the calcareous crustal deposit that is designated travertine, or, more commonly, limestone. Originating in the absence of run-off of rainfall, and high evaporation from the soil, it is very widely distributed. The rain water percolating into the soil and subsoil, where these are appreciably calcareous, dissolves a proportion of carbonate of lime. This, on the withdrawal of the moisture from the soil by evaporation, is carried towards the surface until the solution is so dense that it must drop its load of carbonate. This normally is completed a few inches beneath the surface, and a layer of travertine is formed. It may range from a mere marly seam to upwards of 10ft. of dense rock (the latter was noted above a calcareous sand). A typical section where lime is abundant in the soil would be:—

Soil	3in. to 9in.
Dense travertine	6in. to 24in.
Softer and somewhat chalky travertine in the wetter districts, or nodular to pisolitic travertine, more or less coherent, in the drier districts	1ft. to 5ft.
Calcareous soil or rock	—

Broadly, its distribution may be described as coincident with the agricultural areas, except for the well-drained range country, where conditions are not favorable to its formation.

Consequently a very large proportion of farm buildings and country towns are built of this material. To instance a few only of the towns where it forms the preponderating building stone will serve to indicate the important part played by it in the development of the country:—Balaklava, Beachport, Cowell, Elliston, Edithburgh, Flinders (Streaky Bay), Kadina, Mallala, Moonta, Morgan, Murray Bridge (?), Port Lincoln, Quorn, Robe, Snowtown, Tailem Bend, Tumby, Wallaroo, and Yorketown.

A great deal was used in the building of the older parts of Adelaide and North Adelaide, the stone being obtained in North Adelaide itself and from the adjoining park lands.

The color of the stone is white, cream, and yellowish, and occasionally pink or grey. The best is hard, and breaks somewhat irregularly, so that a considerable proportion of mortar must be used. Some of the stone is rather absorbent, and efficient damp courses should be provided. It is not decorative, but being durable and cheaply won is essentially a utility stone, suitable for rough work or to act as a base for a superimposed surfacing of plaster, cement, or roughcast.

ANALYSES OF MARBLES AND LIMESTONES.

	Grey marble, section 7050, Hundred of Tungkillo.	Ulgerra Gap white marble, sections 18 and 19, Miltalie.	Angaston white marble, section 506, Hundred of Moorooroo.	Angaston pink marble, section 339, Hundred of Moorooroo.	Stockwell white marble, section 219, Hundred of Moorooroo.	Paris Creek (pink), section 3338, Hundred of Kondoparinga.	Paris Creek (white and greyish), section 3338, Hundred of Kondoparinga.	Red dolomite, Mount Gambier, section 724, Hundred of Blanche.	Grey dolomite, section 717, Hundred of Blanche.	Mount Gambier stone—Polyzoal limestone, section 134, Hundred of Blanche.	Polyzoal limestone, "Mount Gambier stone," section 335, Hundred of Hindmarsh	Murray Bridge "Freestone," section 138, Hundred of Burdett.
	%	%	%	%	%	%	%	%	%	%	%	%
Silica (SiO_2)	2·30	7·76	·38	5·04	·54	3·98	2·04	·28	·22	·88	1·50	6·60
Alumina (Al_2O_3)	1·31	·40	·32	1·08	·13	1·42	·85	·12	·24	·28	·45	·70
Ferric oxide (Fe_2O_3)	·11	·13	Nil	·10	·04	·20	·14	·27	·03	·17	·44	1·41
Ferrous oxide (FeO)	·49	·22	·48	·45	·23	·24	·32	·18	·22	·19	·22	·06
Magnesia (MgO)	·73	14·00	·86	1·14	1·14	1·06	3·90	19·50	19·12	·75	1·62	1·12
Lime (CaO)	52·14	37·84	54·08	50·63	54·09	51·33	49·59	32·85	33·30	53·12	51·90	48·84
Soda (No_2O)	·09	·24	·08	·25	·06	·06	·14	·08	·10	·07	·09	·11
Potash (K_2O)	·23	·13	·04	·24	·05	·29	·13	·08	·05	·09	·15	·16
Water at 100°C. (H_2O)	·15	·14	·03	·04	·03	·09	·03	·09	·02	·16	·24	·26
Water over 100°C. (H_2O)	·10	2·46	·13	·38	·33	·21	·29	·59	·66	·42	·90	·84
Carbon dioxide (CO_2)	42·00	35·96	43·59	40·19	43·15	41·00	42·16	45·65	46·05	42·82	42·20	39·54
Titanic dioxide (TiO_2)	·03	·02	·01	·07	·01	·04	·02	·02	·01	·02	·02	·04
Phosphoric anhydride (P_2O_5)	·12	·05	Trace	·15	Trace	·05	·05	·07	·06	·04	·11	·02
Sulphur trioxide (SO_3)	·07	Nil	·02	·07	·03	·03	·04	·14	·15	·10	·20	·14
Chlorine (Cl)	·01	·05	·02	·03	·02	·01	·01	·02	Trace	·02	·02	·01
Ferric disulphide (FeS_2)	—	—	—	—	—	—	—	—	—	—	—	—
Chromium sesquioxide (C_2O_3)	—	—	—	—	—	—	—	—	—	—	—	—
Manganous oxide (MnO)	·16	·02	·05	·05	·02	·01	·06	·02	·02	·01	·01	·04
Barium oxide (BaO)	—	—	—	—	—	—	—	—	—	—	—	—
Strontium oxide (SrO)	—	—	—	—	—	—	—	—	—	—	—	—
Organic matter	—	—	—	—	—	—	—	—	—	Present	Present	—
Total	100·04	99·42	100·09	99·91	99·87	100·04	99·77	99·96	100·25	99·14	100·07	99·89

COUNTY OF ADELAIDE.

HUNDRED OF ADELAIDE.

Adelaide Limestone.

The city of Adelaide is situated on a plain extending from the foothills to the sea, and is underlain by Tertiary fresh water and marine sediments. Among the latter is a bed, ranging in thickness from 6ft. to 22ft., of fossiliferous siliceous limestone. For the most part this is too deeply buried to be available, but where the River Torrens has cut into the plain this bed is exposed, and was formerly quarried along the north boundary of the Government House grounds, and behind Parliament House and the railway station. It is no longer used, the quarries having been filled in, but it is understood that the quarries were not worked out.

The stone is, for the most part, dense and hard, and somewhat costly to dress owing to the silica present, but for the same reason is very durable. Portions of it are seen to be full of small vughs, which, however, do not seem to have affected the wearing qualities. Examples are to be seen in the walls of Holy Trinity Church (circa 1840), North Terrace; in the old portion of the railway station offices; and in the Legislative Council building, which is constructed of this stone, with brick dressings.

It appears probable that this bed either outcropped or was so near the surface in North Adelaide as to give rise to the extensive development of travertine, of which many of the oldest houses of North Adelaide and Adelaide were built.

COUNTY OF GREY.

THE MOUNT GAMBIER OR POLYZOAL LIMESTONE.

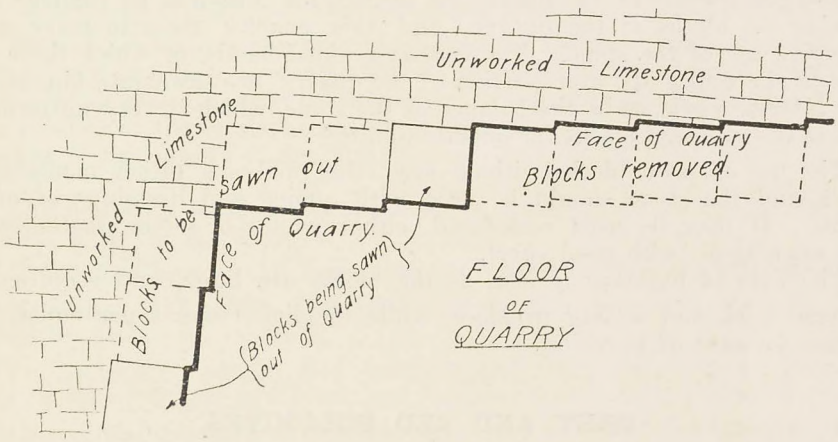
In the Mount Gambier district the polyzoal limestone of Janjukian age is well developed, and in its three variants forms practically the whole of the material used for building.

The main rock is the normal unaltered polyzoal limestone. The next in abundance is the reddish and pink dolomite, while the grey dolomite is comparatively scarce. Both are alterations of the polyzoal limestone.

The polyzoal limestone is very open textured, but varies somewhat in the various quarries. Some is very uniform in grain over a considerable depth; other localities may have a bed of coarser and more porous material, and in some quarries the limestone has a tendency to become chalky and very soft, and to lose its characteristic grain. Some exposures show the presence of small flints and of dolomitic segregations, which cause trouble in the sawing of the stone. A fairly persistent feature is the occurrence of meridional joints, generally filled with harder secondary material, and so standing out in ridges on the bare surfaces of the limestone. Other joints may be simple cracks. The joints cause a little trouble, but are not numerous enough to seriously affect the working of a quarry. The stone, which may have from 0ft. to 2ft. to 3ft. of soil and travertine overburden, is invariably sawn out in pillars about 3½ft. to 4ft. square by the height of the workable bed. The saws used are single-handed crosscut saws, generally with additional teeth on the end of the blade. Water is poured down the back of the cut, and keeps the back and bottom of the cut clear. In taking out the blocks, vertical cuts are used, and the sides of a quarry show a series of offsets of about 4ins., owing to the necessity of giving clearance to the saw handle.

The cuts are carried down to some determined floor, which may be (*a*) a parting, (*b*) a harder bed, (*c*) a coarser bed, or (*d*) a convenient depth. A crane chain is then fixed to the top of the block, and with the aid of bars and wedges the pillar is felled on to the floor of the quarry, to be then sawn either into cubes or into building blocks. The cubes are taken to the building site and there cut up, either by hand, or in some cases by hand and circular saws. The standard block is about 2ft. by 1ft. by 4½in., cut to stand on its bedding on a 4½in. x 2ft. base. Stones for partition walls are cut 6in. thick.

When the sawing into building stones is done at the quarry there is probably a better control of the product, only the normal quality stone being cut into 4½in. blocks, while the abnormal coarser or finer bands are utilised for partition work. The rate for sawing is 2s. per square yard



Plan illustrating the Method of Quarrying Polyzoal Limestone.

cut, for the harder and uniform stone free from segregations, but the price will be somewhat affected by softer stone on the one hand and by segregations on the other.

The stone is very light in proportion to its bulk, owing to the large proportion of voids. A figure supplied by one of the quarry proprietors gave 17½cwts. per cubic yard. A determination by the writer was 78.6lbs. to the cubic foot, or 19cwts. to the cubic yard when air dried, an apparent specific gravity of 1.25. On soaking in water the specimen increased in weight 27.5 per cent. On account of this porosity the limestone is almost always built into cavity walls, and dampcourses are necesary to keep the soil moisture out of the walls. In Mount Gambier the dolomites are used for this purpose in the best class of building, as well as a waterproof dampcourse. In many cases hot tar is applied to a layer until the stone can absorb no more.

Examination of the buildings showed that there are different qualities of stone in the district. The chalky and the coarse open stone fretted badly in some cases, more especially when laid with the bedding planes vertical.

The harder and uniform stone, however, stands very well, and carved work and arrises have stood in the open for some considerable time without ill-effect. Though soft, the stone has the property of hardening very appreciably on prolonged exposure. It is creamy to white in color when

fresh, but gradually darkens to a grey. This greyness is superficial, and the brightness is restored by "dragging" or re-facing the wall by scraping it with a serrated tool or by rubbing with a piece of similar stone or a wire brush. The stone may also be painted if desired, but at the expense of its distinctive character. The climate is wet (for South Australia), 31.8in. being the average rainfall at Mount Gambier, but there appears to be no trouble due to damp when cavity walls and dampcourses are used.

It is used chiefly in the form of sawn slabs for the main portions of the walls, either alone or with foundation courses, quoins and dressings of grey of pink dolomite or even brick. In some cases the pink dolomite is the main stone with dressings, quoins, &c., of the polyzoal limestone. This latter use is wrong, as the limestone is not capable of withstanding the harder usage endured by corners as the dolomites are.

The proprietors of the quarry on section 134, hundred of Blanche, are sawing up blocks at the quarry, and this enables them to make more effective use of the stone. The coarser-grained bands, of which there are two in the upper 3ft. over portion of the quarry, are sawn into 6in. blocks for interior work, while the balance of the stone, which is very uniform, is cut to the standard blocks for outside walling.

The use of sawn blocks without any relief makes a rather monotonous wall, and the stone should be used with quoins and dressings of other stone. It may be used rock-faced, either wholly or in conjunction with the sawn stone, with good effect.

The rate of building is fast, as the blocks are large, and require less mortar work and setting in place, while the light weight per cubic foot makes for ease of handling.

GREY AND RED DOLOMITES.

These are probably two of the most durable of the South Australian stones.

They occur in the hundreds of Blanche and Hindmarsh as superficial deposits in the polyzoal limestone, and carry the same fossils.

There is no doubt but that both the grey and the pink or red dolomite are due to the alteration of the polyzoal limestone by magnesian solutions, indeed, the analyses on page 37 show that the two dolomites are practically identical in composition. The red, however, contains a quarter of one per cent. of ferric iron more than the grey, and the difference in color is due to this small amount of ferric oxide.

The origin of marine dolomites of this type is discussed by Clarke in Data of Geochemistry (Bull, 695, U.S.G.S.), who gives the following summary on page 570:—

"First, the mixed carbonates may be directly precipitated in shallow waters, either by changes of temperature and concentration of atmospheric CO_2, or by ammonium carbonate produced by the decomposition of the remains of marine organisms . . . Second, the carbonates contained in the shells of skeletons of the marine invertebrates are decomposed. Third, magnesium carbonate is concentrated by the leaching away of the more easily dissolved calcium salts. Fourth, the so-called corralline rock is enriched at the expense of the magnesium salts contained in sea water. All four processes may be in operation simultaneously. . . . The fourth process, however, is generally the most important, and it precedes the union of the carbonates into true dolomite."

When the composition of the polyzoal limestone is considered it is probable that the second and third processes are not important. The other two may have acted simultaneously in shallow arms of the sea, in which concentraton of sea water was pronounced.

The finer grained lime carbonate has been entirely altered to a finely crystalline dolomite, of much greater weight per cubic foot and much more compact. There is still a small proportion of voids in the stone, but it cannot be classed as pervious.

The dolomites, unlike the limestone, cannot be sawn, but must be broken out with plugs and feathers, and are used scabbled or "rock-faced." They are also carved into columns, and both are extensively used in Mount Gambier for base courses, quoins and dressings, and even for main walls. In some cases the grey dolomite is carried up for several feet above the ground level to resist wear and abuse, and above it the limestone is used.

Both the dolomites are very handsome and durable stones, but are comparatively expensive to quarry and to dress, while the royalty charged on the grey dolomite is stated to be such as to seriously check its use. It may be mentioned that the mineral rights are alienated from the Crown, and belong to the owners of the land.

The following buildings were noted as examples of the use of the local stones in Mount Gambier:—

Methodist Church: All limestone; very slight weathering after 60 years.

Methodist Hall, 1903: Grey dolomite base courses, red dolomite front body limestone; all excellent.

St. Andrew's Church: Red dolomite and limestone facings. Some of the limestone is bad and frets, and has also been used on edge.

Commercial Bank: Red dolomite with grey dolomite and limestone trimming. Good.

E.S. and A. Bank: Red dolomite front and columns grey dolomite, trimmings in base course, and limestone trimmings above. All good.

Institute and Town Hall: Pink dolomite fronts (rock faced). Grey dolomite in base course and doorways, balance of trimming limestone. Good.

Savings Bank: Base course red dolomite, front and base of sides grey dolomite, sides limestone. Good.

Post Office: Rockfaced grey dolomite. Red dolomite columns and Mintaro flagstones in verandah.

Caledonian Hall: Front, grey dolomite and limestone dressings, side walls limestone. Good.

An example of its use may be seen in Adelaide in the form of small pillars or columns of red dolomite at the main door of St. Peter's Cathedral.

Polyzoal Limestone.

A very large number of quarries have been opened on the polyzoal limestone throughout the vicinity of Mount Gambier, and only some of them were visited.

The chief workings are at Compton, in the hundred of Blanche, about six miles west of Mount Gambier.

Section 134, Hundred of Blanche.

Roofs and Ceilings, Limited.

On this section is a quarry about 12,000 sq. yds. in area on the flat-lying polyzoal limestone.

A generalised section shows:—

Soil and travertinous limestone	0ft. to 1½ft.
Open textured inferior stone	0ft. to 3ft.
Uniform even-grained medium-hard stone (the standard quality)	10ft.

The floor of the quarry is a parting above a thin hard bed, and then, on the evidence of a bore, the polyzoal limestone is believed to extend to at least 65ft. below the surface.

A few meridional cracks or "shakes" exist, but cause little trouble, and there is an almost complete absence of hard segregations.

The 0-3ft. of open-textured stone is cut up for interior work. There is practically no waste at the quarry except that caused by an occasional solution cavity extending from a few inches to 3ft. or 4ft. into the limestone. On the average depth of 10ft. of saleable stone that the quarry has yielded, the output has been about 40,000 cubic yards, reckoned equivalent to about 400 houses. There appears to be ample scope for extension except in the south-east corner, where the stone is abnormally soft and is left. A typical sample of the 10ft. of average stone after air-drying was found to weigh 78.6lbs. per cubic foot* (as against marble 169lbs. per cubic foot), and to be capable of absorbing 21.4lbs. of water per cubic foot. This capacity for absorption is equivalent to a pore space of 34.6 per cent., but on the relative weights per cubic foot of the limestone and of calcite there must be over 50 per cent. of voids.

The analysis of a representative sample is given on page 37.

The plant includes a steam-driven circular saw for cutting up the stone to builders' requirements.

Section 141, Hundred of Blanche.

F. Major's Quarry.

This section lies immediately to the north of section 134, and contains very similar stone, slightly more open textured and a little softer to cut. It is free from segregations. The quarry is U shaped owing to the presence of a number of meridional shakes or joints, which have caused portion of the deposit to the left. The quarry is estimated as between 7,500 sq. yds. to 8,000 sq. yds. in area, and to have yielded an average depth of 8ft. of stone, or approximately 20,000yds. This quarry is capable of very considerable extension.

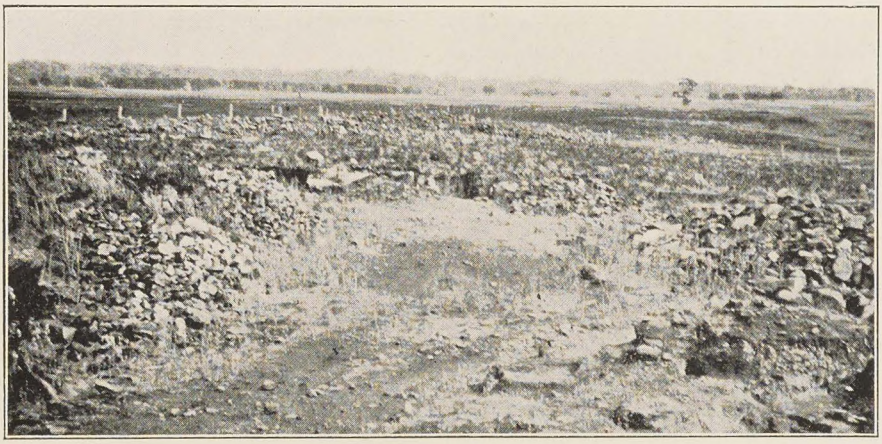
Section 140, Hundred of Blanche.

McKay's Quarry.

The workings on this section are 180yds. by 50yds. in area, and 3ft. to 13ft. in depth. The stone is intermediate in texture between sections 134 and 141, and of excellent quality. The stone is free of dolomitic segregations, but there are a large number of "shakes," both vertical and dipping 40°, which cause waste in quarrying. These "shakes" may be mere joints or may carry a filling of carbonate of lime (travertine) and a little dolomite. When possible the output of the quarry is in the form of large cubical blocks, but the irregular blocks caused by shakes are sawn into building stones at the quarry to reduce the proportion of waste.

* It may be noted that with the exception of certain rhyolitic tuffs mentioned by Merrill ("Stones for Building and Decoration"), this is the lightest stone used for building of which there is a record.

Sawing Polyzoal Limestone into Building Blocks, near Mount Gambier.



Quarry of Red Dolomite, Section 385, Hundred of Blanche.

Red Dolomite, "Up and Down Rocks," Section 213, Hundred of Hindmarsh.

To face p. 43.]

Section 144, Hundred of Blanche.

T. R. Walter's Quarry.

A comparatively new quarry, about 150ft. by 70ft., has been opened on this section on a medium grained and very uniform bed of polyzoal limestone, which is free from flaws. There is practically no overburden, and about 6ft. of stone is being taken out.

The section here is:—

Information given by trial holes { 0-6ft. high-grade stone; 6ft.-9ft., coarse and rubbly stone; 9ft.-12ft., very good stone

Only the upper bed is worked. The stone has gone to several towns in the South-East and to at least one in Victoria.

The above described group of very important quarries are all within a mile and a half of the Mount Gambier-Millicent railway, but are from three to five miles from Compton, the nearest station, and six to nine from Mount Gambier. Yet despite the road carriage they have not only supplied much stone to Mount Gambier, but their product has gone by rail to the various South-Eastern towns, to Melbourne and western Victoria, and to Adelaide.

Section 524, Hundred of Blanche.

R. White's Quarry.

A quarry 2½ chains by 1 chain has been taken out to a maximum depth of 12ft. There is no overburden. The upper half of the face is variable in grain, and contains nodules and streaks of flinty and dolomitic material. The lower portion is much more uniform and less affected by segregations.

In addition to the quarries above described, there are many smaller ones in the hundred of Blanche to the west and N.W. of Mount Gambier that were not visited.

Section 209, Hundred of Hindmarsh.

The polyzoal limestone has been worked to a depth of 2ft. to 5ft. over an area of 100yds. by 30yds., and the bed that had been worked appears to be thinning out.

Section 335, Hundred of Hindmarsh.

A quarry in the eastern corner of this section, about 100ft. square, exposes from 1ft. to 8ft. of stone under from 0ft. to 3ft. of soil and travertinous overburden. Some of the stone is excellent, but some is too soft and irregular in grain, with friable, chalky patches. Occasional flints and hard, dense grey dolomitic segregations occur. The bottom stone is very soft owing to the quarry water. The quarry has reached the road to the south, cuts out to the north, and can only extend to the westward.

A sample of the average quality material was taken, of which the analysis is shown on page 37.

Section 337, Hundred of Hindmarsh.

An old quarry, 250ft. by 150ft. by 5ft. average depth of stone removed, shows a soft and somewhat uneven stone that hardens on exposure. The faces show a tendency to blacken after some years, owing to the growth of organic matter. A branch from the main quarry, 90ft. by 50ft. by 8ft. deep, is the last area worked. The stone is very soft and tender, owing to the

presence of chalky carbonate of lime, into which a proportion of the polyzoal limestone has been converted. It is free of flints. The stone is cream when freshly cut, but becomes white with the loss of the quarry water.

Red and Grey Dolomites.

The dolomites have been worked to a considerable extent, but the quarries are not prominent features, as the waste is thrown back on to the worked-out ground, and builds the surface up almost to the original level. Unlike the limestone, it has to be broken out with explosives and plug and feather work.

The grey dolomite, which is relatively scarce, has been worked principally on sections 717 and 721, hundred of Blanche. It occurs over an area of probably not less than 300 acres.

Section 717, Hundred of Blanche.

This appears to be the principal deposit that has been worked, and the workings are on a low rise of several acres. The stone varies in hardness; some is very soft and rotten, and some is badly jointed. The quarries were worked to a depth of about 6ft., but the bottom of the stone was not seen by the writer. From the quantity of waste that has been thrown back it appears probable that about half the stone broken has been removed. Large blocks are stated to have been obtained on this section. An average sample was taken here, and the analysis is given on page 37.

Section 721, Hundred of Blanche.

The bulk of this section is underlain by the grey dolomite, and several openings have been made on it. The principal one has an area of about an acre, and has been worked to a depth of 2ft. to 4ft. The rejected material thrown back on the worked ground restores the surface to practically its original level, indicating that the proportion of usable stone is about one-third of that broken. Small building stones (''shoddys'') were obtained from these quarries.

Red Dolomite.

This stone is much more abundant than the white, being recorded on sections 385, 724, 726, 727, 158, 165, 166, and 180, hundred of Blanche, and on sections 213 and 204, hundred of Hindmarsh. In texture it is normally granular-crystalline, but ranges to micro-crystalline. Occasional small openings are visible, due to incomplete filling of cavities and joints during the crystallisation of the dolomite. The stone breaks readily, and is generally used ''rock-faced,'' though columns and smooth-dressed faces are not uncommon.

The density makes the charges for transport per cubic yard considerably more than for the polyzoal limestone.

The color ranges from salmon-pink through brick-red to terra cotta. It is or has been worked on the following sections:—

Section 385, Hundred of Blanche.

Half a mile to the north-east of two large quarries (sections 134 and 141) on the polyzoal limestone, there is a considerable area of pink dolomite which has been worked to some extent. There is no overburden, and the stone has been worked to a depth of 3ft., with pink dolomite underfoot. Close by the principal opening is a patch of a few square feet of polyzoal limestone overlying the dolomite, thus proving that the dolomite is part of

the polyzoal beds that has suffered alteration with destruction of the majority of the organic structure, only the larger shells being left unchanged. The bed is of good quality, and should yield a large quantity of stone when required.

Section 724, *Hundred of Blanche* (*Shelton's*).

This section has been one of the main producers of pink or red dolomite, and several comparatively small openings are scattered about the western portion of the section. The principal working showed from 6ft. to 8ft. of overburden, consisting of decomposed dolomite (or granular dolomitic sand), on 6ft. of good quality pink dolomite and no bottom. Large blocks are obtainable here, and the area is large. The depth of overburden at the quarry seen is abnormal for the district. An average sample was taken here, the results of which are given on page 37.

The road passing the south boundary of this section crosses several exposures of the red dolomite adjoining the sections enumerated above.

Sections 213 *and* 204, *Hundred of Hindmarsh.*

The first section is a "stone and road reserve," and contains the line of vertical cliff, about half a mile in length, known as the "Up and Down Rocks." The vertical portion of the cliff, about 30ft. in height, shows the horizontal edge of a bed of dense pink dolomite resting on a lower bed of somewhat buff color. A talus of dolomite blocks and soil intervenes for a few feet, and then a bed of chalky polyzoal limestone, partly replaced by pink dolomite throughout its mass, has been opened in a small quarry. This material is still soft enough to saw, as the dolomitisation has not been very complete and has been uniformly diffused through the mass. At a still lower level is a fairly hard, compact, chalky limestone of yellowish tinge that has been worked a little.

The important stone of this locality is the hard dolomite which occurs in vast amount. There is a good deal of honeycombing in the face of the cliff and vermicular channels along the joint planes similar in type to, but smaller than, those developed in the Murray Bridge "freestone," which, like the dolomite, is an indurated form of the polyzoal limestone.

The deposit is situated within a mile of the Beachport railway, but 2½ miles and 3½ miles from Holloway and Tantanoola stations. Stone could be shipped from Beachport (30 miles distant) if required. Its weight per cubic foot, compared with that of the polyzoal limestone, renders railway carriage unduly expensive.

MARBLE AND LIMESTONE.

COUNTY OF HINDMARSH.

HUNDRED OF KONDOPARINGA, SECTION 3338.

Paris Creek Marble Quarry.

This deposit of marble was acquired by the Paris Creek Marble Quarries Ltd., and reopened in 1921. The beds dip at a high angle to the eastward, and have a width across the strike of approximately 10 chains, and are exposed for over 30 chains within this section along a strike varying from N. 13° W. to N. 5° E. To the south it extends beyond the property, and to the north it is probable that its extension could be traced to the Macclesfield quarry. It is seen at intermediate positions, and though the strikes are different, the bed may have been folded or faulted. The colored marbles of the two localities are very similar.

In section 3338 a small stream (Paris Creek) follows the general line of strike, and divides the deposit into two zones. Outcrops are not conspicuous owing to the shallow soil cover, but sufficient exposures are present to prove the essential continuity of the marble body. This, however, varies in quality across the strike. There are some portions that are argillaceous, others shattered, and some, at the surface at least, sugary. There are two irregular quarries on the western side of the valley, but they are, comparatively speaking, insignificant in relation to the stone existing. Their irregularity is due to their small size and to the marble being still affected by superficial weathering along joint planes.

The marble ranges in color from pure white, through cream, to various shades of bluish-grey. In the south part of the section, near creek level on the western side, is a very dark-grey or almost black medium-grained marble that is unlike any hitherto worked in the State, and which might be worth a trial, though it does not take a high polish.

The lighter-colored marble is for the most part best developed on the west side of the creek, though there are light bands, known but not opened, on the eastern side, where darker grey marble predominates. There has recently been discovered on this side a bed of medium-grained pink marble that is full of life, and promises to be capable of taking a high polish and to be obtainable in large blocks. Its composition is shown by the analysis on page 37, where there may also be seen the analysis of an average sample of the Paris Creek marble, as exposed in the different openings. This average sample shows that the marble waste may be burned to a satisfactory lime if so desired.

The bulk of the stone here is fine to medium grained, only a few of the exposures showing coarsely crystalline marble.

Some of the white marble is very fine-grained, surpassing, in this respect, anything hitherto quarried in the State, but large blocks of this grade are comparatively scarce. The stone takes a high polish, and finds a ready market. Some of the clouded marble is particularly attractive. Odd particles of pyrite were noted in some of the blocks, and occasional blocks are traversed by thin veins of quartz (the so-called "glass veins"). These veins are a not uncommon feature in marble beds, and their effect must be minimised by judicious quarrying of blocks which are to be sawn into slabs.

The machinery erected here consists of a semi-portable return tube boiler, steam engine, air compressor and rock drills, pump, one multiple blade gang saw, one rubbing table, one grinder, one polishing table, and a set of carborundum wheels designed to cut sawn slabs to any required dimensions. Additional saws are being installed. The company is fortunate in that, close to the western side of the deposit, there is a bed of quartzite about a chain in width, which, on weathering, becomes successively a friable sandstone, then honeycombed, and finally breaks down to a peculiarly sharp, siliceous sand. This sand is, of course superficial and *in situ*, but it only requires screening to remove the stony particles to render it fit for an abrasive on the saws and rubbing table. It is present in considerable amount. Washing the screened sand in an upward current classifier would increase the efficiency of the saws and rubbing table, and would, if desired, enable the excess of sand from the saws to be cleaned and re-used. The installation of such a washer and of an automatic sand feed to the saws would undoubtedly reduce the cost per superficial foot sawn.

The finished product is at the present time carted to the railway, a distance of eight miles, and trucked either to Melbourne or Adelaide. For the latter market, however, it is proposed to use a motor truck to reduce handling, risk of breakage, and the high railway freight rate on sawn and polished slabs.

Hundred of Macclesfield, Section 2827.

Macclesfield Quarries.

This section, now held under lease by the Paris Creek Marble Co., which owns and operates the Paris Creek quarry, has long been known as a producer of colored marble, although the output has not been very great compared with the stone available. It was used to face the weir built across the Onkaparinga River at Clarendon, in connection with the Happy Valley reservoir. At Strathalbyn the Roman Catholic Church has been built of rock-faced Macclesfield marble. It has also found extensive application in the form of memorials and monuments throughout the State. In many cases these have been erected long enough to enable a very fair idea of the good weathering qualities of the stone to be formed.

There are three main openings, all within a radius of 100yds. The north-easternmost one has not been worked for many years. Of the others, the eastern quarry yields a medium-grained grey marble. The third quarry yields a stone having a prevalent pink tint, with lenticular patches and streaks of grey. The value of this stone, both for exterior work and inside decoration, is well established, and the coloring and marking are most distinctive.

The marble beds here dip to the S.E. at 35°, and are sound to the surface. The exposures around the quarries show that there is a very large quantity available, presenting no difficulty in working.

Other tints have been obtained from this group of quarries in the past, notable among which are a cream-colored stone and a pale grey variety with dark veins and streaks, and these stones are well worthy of a search to re-locate them, so that a wider range of colors may be produced.

These quarries are situated about four miles from Bugle Ranges station (40 miles from Adelaide), where the stone is trucked. Some, however, is carted to the marble cutting works at Paris Creek quarry (section 3338, hundred of Kondoparinga), to be sawn into polished slabs.

Hundred of Myponga, Section 265.

Immediately to the north of the alunite workings at Carrickalinga Head a bed of black sub-crystalline limestone is exposed at the foot of the cliff. The bed dips to the north-north-west, and it should be possible to pick it up on the top of the cliff.

The stone is black, with occasional veins of calcite, and takes a very fair polish. When seen by the writer, some years ago, the locality was rather inaccessible, but the erection of a jetty about a mile distant has modified the problem of transport.

The stone might find a use in sawn slabs, and would supply a color not worked in the State.

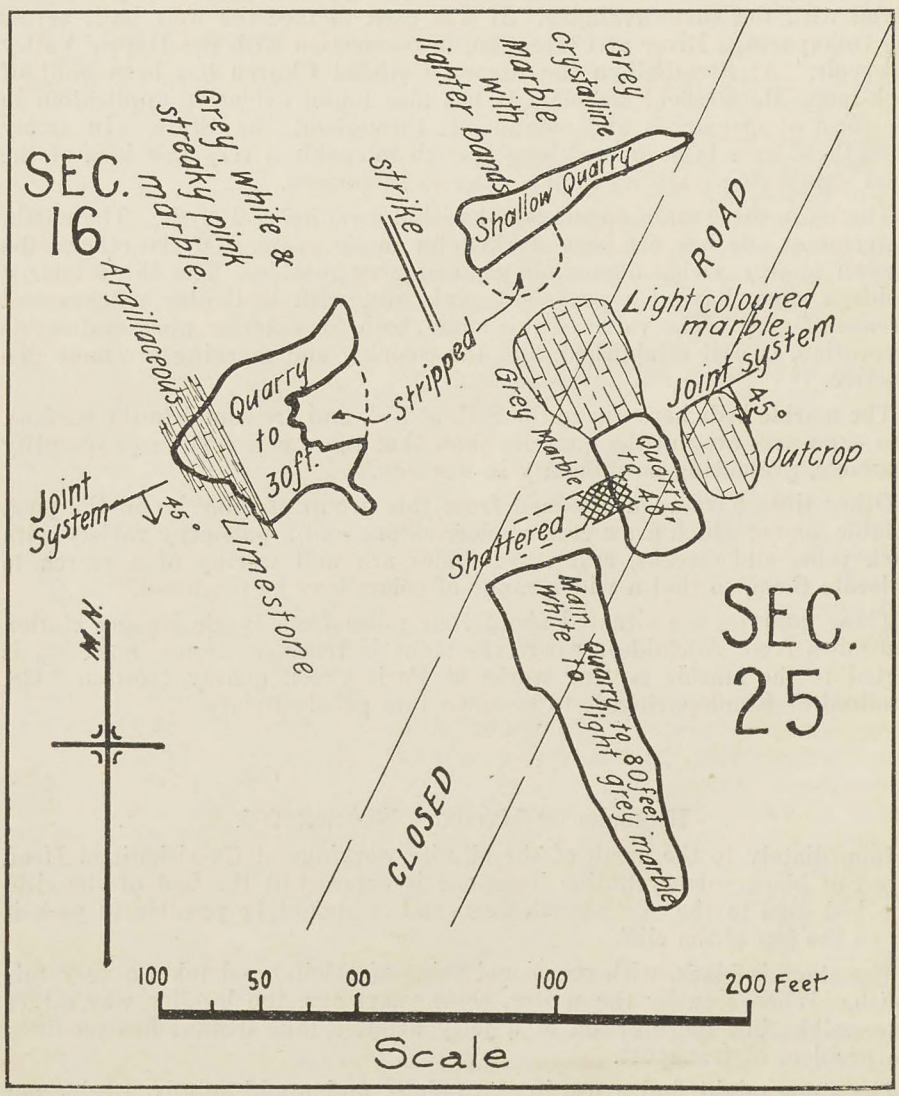
COUNTY OF LIGHT.

Sections 16 and 25, Hundred of Belvidere.

Carrara Marble Quarry.

The stone that is generally referred to as Kapunda marble was taken from this quarry, which lies about eight miles by road from Kapunda station. The marble is the extension of those beds which are associated with the phosphate deposits of St. John's, to the north-west.

The site of the Carrara quarries is level, and the outcrops are largely covered by soil. Four quarries have been opened, and show the marble to strike N.N.W.-S.S.E., and to be vertically bedded and bounded on the western side by argillaceous limestone.



Plan of Carrara Quarry, Sections 16 and 25, Hundred of Belvidere.

Two joint systems, dipping 45° to S. 30° E. and N. 30° W. respectively, are visible. The joints have permitted solution of the limestone to some depth, and the joints contain residual, sandy, and argillaceous clays.

The level ground has forced the working of the marble to be done by pits, served by derricks. There are four quarries, and considerable variation in the marble is noted in them.

The main, or southern, quarry, about 160ft. along the strike x 40ft. x 80ft., exposed white to light-grey marble of medium grain, and provided much of the stone used in the construction of Parliament House, Adelaide.

Twenty feet east of the north corner of the main quarry, and separated from it by a wall of grey marble, is the second quarry, 70ft. along the strike by 35ft. wide by 40ft. deep. There is a badly fractured zone 20ft. to 30ft. in width crossing the quarry at right angles to its length. The stone from here appears to have been a little lighter in color than that from the main quarry. There is an area of light-colored to whitish marble, 50ft. x 80ft., exposed adjacent to the N.N.W. face of this quarry, and marble outcrops for 40ft. east of this quarry.

A third excavation 130ft. to the north has been made for a length of 120ft. across the strike, and to a shallow depth. It appears to have been a prospecting opening crossing the strike and exposing a grey, fairly coarse-grained marble with lighter bands.

The fourth quarry lies to the west of the others, and is an irregular excavation about 110ft. x 80ft., and up to 30ft. in depth. The marble is grey, with a small proportion of white and streaked with pink. The excavations prove the bed to be vertical, over 280ft. in width, and they extend for 400ft. along the strike. The quantity available is thus very large, and these quarries show very little waste. The best-known example of its use is the Parliament House, but many buildings in Kapunda have been constructed from it, and large sawn slabs have been used in that town for the footpaths. The waste was used for road metal.

The quarries have not been worked for some years, but are capable of great extension if their type of marble is desired. The rate of working should be on such a scale as to enable various grades (governed by color and grain) to be made in such quantity that the least abundant should be in sufficient quantity to be saleable. In the past the stone was carted eight miles over a good but hilly road to Kapunda. Now there is a railway station (Stockwell) within six miles by a level road. The working conditions are good, water was not within 80ft. of the surface, and the vertical bedding and transverse joint systems make for ease in breaking out the blocks.

Section 116, Hundred of Belvidere.

A considerable extent of marble occurs in this and the adjoining section (115). An opening shows the marble to be white and fairly coarse grained. No work has been done upon it other than the removal of a few cubic yards of stone.

Hundred of Moorooroo, Section 219.

Stockwell Marble Quarry.

The hundred plan shows the name of Carrara Hill on this section, an allusion to the deposit of marble that outcrops immediately to the eastward of Stockwell Station.

The bed outcrops for about 100yds. in width, and strikes S. 30° E. (Mag.), with a dip of about 70° to the W.S.W. To the northwards it is concealed by the Tertiary plain to the west of Stockwell. To the S.S.E. it extends into section 220, where it is faulted to the westward, and then extends still further to the S.S.E., being opened by a quarry beside the road separating sections 200 and 199.

In the vicinity of Stockwell quarry the eastern portion of the outcrop shows a white marble, but near the southern boundary of the section there is more grey present. The western portion of the bed is greyer and more argillaceous. The material has been used locally for buildings and for road making. The quarry, somewhat irregular in shape, has extreme dimensions of 300ft. by 240ft., and a maximum depth of 35ft. The western half of the quarry exposes calcareous slates with small bands of bluish-grey medium-grained marble, some of which contain an appreciable amount of pyrite.

The eastern half of the quarry is occupied by two beds of light-colored marble separated by a shattered and argillaceous calcareous zone about 15ft. to 20ft. thick. The western bed, perhaps 30ft. thick, is medium grained, with a slight pink color tinged with grey and with veinings of darker grey. The eastern body and the eastern wall contain a very white marble, slightly coarser in grain than the western bed, and containing no pyrite. The stone shows brownish yellow stains along joints and cracks.

The quarry and the outcrop show the stone to be badly affected by joints. There are:—

(1) Bedding joints, dip 70° W.S.W.
(2) Joints parallel in strike to bedding and dipping 45° E.N.E.
(3) Joints crossing the strike and dipping 80° N.N.W.
(4) Irregular fractures.

In consequence there does not appear to be any prospect of obtaining dimension or monumental stone from this quarry. Still the stone is very attractive, and can be cheaply got out as small stones to be used as "builders" and in "crazy" work.

Situated 200 yards from the siding and 53 miles by rail from Adelaide, the body is in a position to supply a high-class durable stone in small blocks, at a cost that would compare favorably with stone brought by road from the hills to the east of Adelaide.

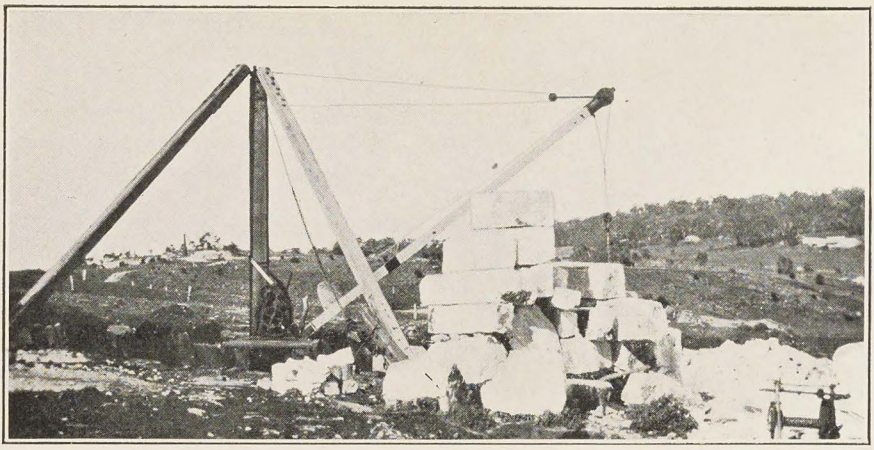
The chemical composition, shown by the analysis on page 37, is essentially that of calcite, the sample containing 96.6 per cent. of carbonate of lime. It could, like the Angaston marble, find a use in the manufacture of high-grade lime.

Hundred of Moorooroo, Sections 506 and 339.

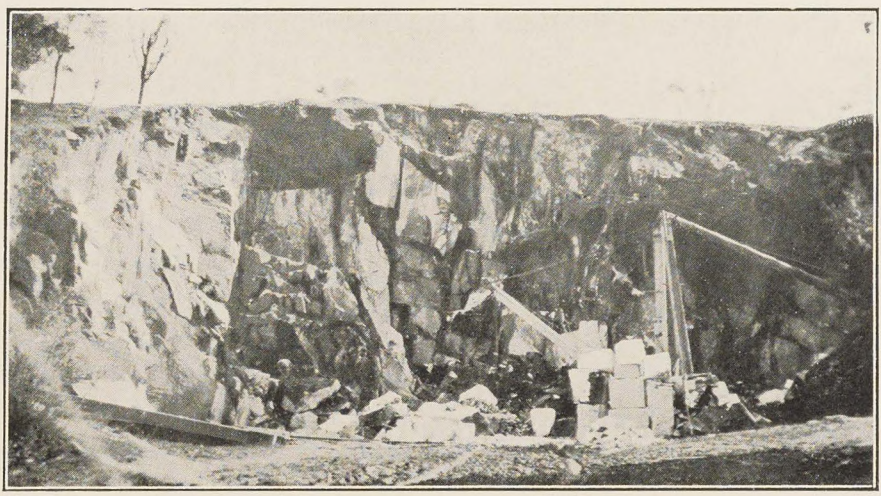
Angaston has long been known for its marble, which is used in the construction of a large proportion of the buildings in the town.

The main deposits that have been and are worked, are situated on sections 506 and 339, hundred of Moorooroo, approximately $1\frac{1}{4}$ miles to $1\frac{3}{4}$ miles south of the railway station.

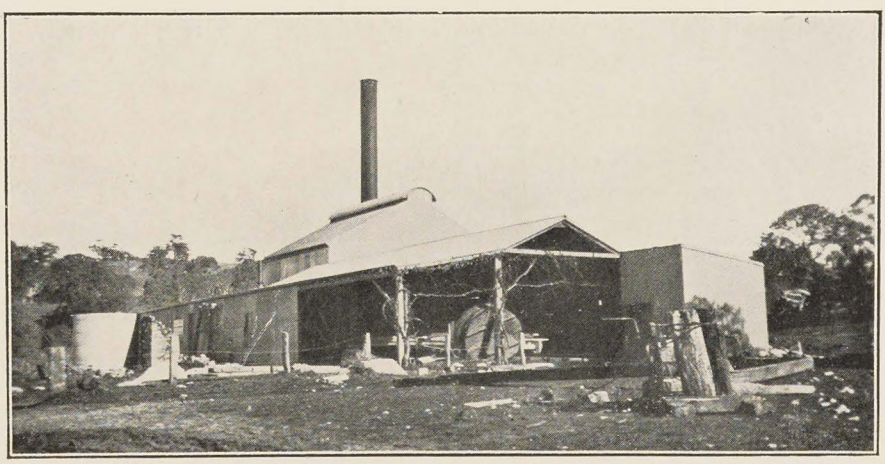
The marble forms a hill, rising above the surrounding orchard country, about half a mile long and 10 chains wide, giving an area of 40 acres of marble, less a few argillaceous bands and some amphibolite dykes. The longer axis of the hill (N.N.W.-S.S.E.) is the strike of the beds, which



Angaston Marble Quarries, Looking S.S.E. along outcrop, Sections 339 and 506, Hundred of Moorooroo.



Angaston Marble Co.'s South Quarry, Section 506 Hundred of Moorooroo.



Angaston Marble Co.'s Dressing Plant, Section 506, Hundred of Moorooroo

To face p. 51.]

are vertical. There are two joint systems, one parallel with the bedding planes, and the other vertical and striking E. 20° N. or across the strike of the bed. These planes facilitate the quarrying.

Near the southern end of the marble hill is the new dressing plant of the Angaston Marble Company, Limited. The plant, substantially housed to allow for extension, includes a gang-saw and polishing table, and is driven by a large compound non-condensing engine, supplied with steam from a Babcock & Wilcox boiler. Water* is got from a well, 65ft. deep, in the schist to the west of the marble and south of the powerhouse.

Two quarries are being worked by the Angaston Marble Company, one by G. E. Morgan, and one by W. Laycock. There are at least eight or nine smaller quarries that have been opened in the past, and are not now operated, although the marble in them is practically identical with that now being worked.

The marble persists right to the surface, where it outcrops as flat sheets or as the rounded top of boulders produced by solution along joint and bedding planes. Some boulders, especially of the coarser varieties, show a sugary and incoherent texture for a few inches in depth, but the great majority of the stone is sound to within ½in. to 1in. of the surface, whether this be an outcrop surface or a joint. Water level being at least 60ft. below any existing faces, percolation has enabled solution to take place along joint and bedding planes, and the resultant openings, up to a few inches in thickness, are filled with red ferruginous clay. The total bulk of this clay and of the overburden is small. A few "glass veins" occur in the marble, generally very thin. A section of one showed a little pyrite, pale and dark mica, and quartz, in addition to carbonates. The marble is bounded on the east and west by mica schist, and small dykes of amphibolite traversing the marble were noted on the south property of the Angaston Marble Company and in Morgan's quarry.

Microscopic examination of this rock shows it to consist of hornblende and a good deal of quartz. The rock has been entirely reconstituted, and

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* An analysis by W. S. Chapman of this water, and dated 28/9/1921, is as follows:—

	Grains per Gallon.
Chlorine (Cl)	6.44
Sulphuric acid radicle (SO_4)	0.37
Carbonic acid radicle (CO_3)	18.41
Sodium and potassium (Na & K)	11.34
Calcium (Ca)	2.93
Magnesium (Mg)	1.96
Silica (SiO_2)	1.75
Total saline matter, grains per gallon	43.20
Total saline matters, ounces per gallon	0.10

Assumed Composition of Salts.

Calcium carbonate	7.32
Magnesium carbonate	6.86
Sodium carbonate	16.11
Sodium sulphate	0.55
Sodium and potassium chlorides	10.61
Silica	1.75

Hardness.	English Degrees.
Total	15.50
Temporary	15.50
Due to calcium	7.32
Due to magnesium	8.18

large crystals have been altered until their presence is indicated only by patches in optical continuity. The rock has been a crystallised basic dyke, altered until it is a hornblende schist.

The southern quarry, that of the Angaston Marble Company, adjoins its works, and was formerly worked by W. Sibley. It cuts into the hill from the base level, and exposes a face about 50ft. in height and 80ft. to 100ft. in width. The quarry at one time was carried below the present level, but the rise of the hill to the north has given a face of ample height for quarrying large blocks. Opened over 30 years ago, this quarry has produced much of the marble used in Angaston. In Adelaide some of the very large blocks of Parliament House and the Burns' statue on North Terrace are examples of its use. It finds a market in Adelaide, Melbourne, and Perth for monumental work and sawn slabs. Five thousand cubic feet are stated to have been sent to London, and to have been used in the interior of Australia House with excellent effect. The colors exposed in this quarry are white, a light bluish grey, and a light pink, and gradations of these colors. The white is the most common and the pink the least. An analysis of the typical white is given on page 37.

The stone sold to local builders (medium-sized blocks of somewhat irregular shape) compares in price quite favorably with the slate and freestone round Adelaide, which are sold for a few shillings a ton, when the quality of the stone is considered.

Dimension stone is sold by the cubic foot, and is many times dearer than the irregular blocks owing to the cost of dressing to specified shapes and sizes.

Just beyond the limits of the Angaston Marble Company's ground is a recent quarry (Laycock's), about 30ft. square. The marble is massive, and capable of yielding very large blocks. The bulk exposed is a very coarse-grained white, but there is some light greyish-blue and a little light pink. To the north-west of this quarry, and still on section 506, hundred of Moorooroo, is Morgan's quarry, 100ft. by 25ft., and up to 30ft. deep. The quarry is on a band of coarse white and bluish-white marble, and light pink stone is visible on the east side and bluish-pink on the west.

The larger blocks are used for monumental work, and local building material is also supplied from this quarry.

Four chains to the westward an unworked quarry shows coarse-grained whitish-grey marble with darker bands.

On crossing the road into section 339 two small unworked quarries are seen. They were opened by Herring on a white and fairly coarse marble, and yielded blocks for the die and pedestal of Sturt's statue in Victoria Square. A short distance to the north-east is another small quarry, notable as the source of a handsome coarse-grained rose-pink marble, which in places contains small specks of biotite.

To the N.N.W. of Herring's quarries is the northern quarry of the Angaston Marble Co., formerly Fischer's. The quarry is a pit about 25ft. to 30ft. deep, and shows the marble to have joints (bedding planes) striking N. 40° W., with an 80° dip to the S.W. The marble as a whole is white, merging into light grey. There are brownish and greyish veins in some of the stone, due to brown mica and infrequent quartz or quartzite veinlets.

The area of the outcrop chiefly worked is approximately 40 acres, and the bulk of it is capable of yielding building stone and higher grade material. The proportion so far removed is, comparatively speaking,

neglible. A feature of all the quarries is the almost entire absence of waste. There is a little soil left, but all rock broken is disposed of as:—

(1) Monumental and sawn work (chiefly by rail).
(2) Building stones (chiefly local).
(3) Road metal.
(4) For lime burning—a small demand.

The use of it for road metal is confined to the district, where it is outstandingly the cheapest material available. It is too soft to be entirely satisfactory, grinding to dust in summer, and making muddy roads in winter, but the material has a property of cementing together under light traffic, and is an example of the successful utilisation of an otherwise waste product.

On the eastern portion of section 506, and separated from the chiefly worked bed of marble by mica schist, is a second bed of very similar type, on which W. Laycock has a quarry.

Other marbles are worked within the district, but only for local use. An example is the coarse grey marble used in the Angaston Institute, and that from section 429, hundred of Moorooroo, used in the construction of the Yalumba winery.

COUNTY OF JERVOIS.

Hundred of Miltalie, Sections 18 and 19.

The Pre-Cambrian rocks of Eyre Peninsula include many marbles, for the most part in inaccessible positions. In the ranges to the west of Cowell there are a number of exposures that may in time be utilised.

One of these, in Ulgerra Gap, is a large bed striking N.E.-S.W., through sections 18 and 19, hundred of Miltalie. The marble is white in color and saccahroidal in texture. There are yellowish stains in some of the stone, but only outcrop exposures are available. As far as could be judged from such exposures the stone is sound.

Chemically the analysis on page 37 shows it to be dolomitic.

COUNTY OF RUSSELL.

Hundred of Burdett.

Murray Bridge "Freestone."

The so-called Murray Bridge freestone is the polyzoal limestone of Jankukian age that is exposed along the banks of the Murray. It is principally worked on the left bank of the river for about three miles below Murray Bridge. The quarries extend along the face of the cliff, but have not been worked back to any extent. Probably the two largest individual quarries are on sections 138 and 139, hundred of Burdett. The upper 20ft. is exceedingly corroded by percolating water, and only very occasional blocks of dimensional stone would be got in removing this overburden. Below this is some 20ft. of limestone, also horizontally disposed, from which practically the whole of the "freestone" is obtained. There are in this bed horizontal partings 2ft. to 8ft. apart, and a number of vertical joints. Much of this bed is badly affected by solution pipes, which may be empty or filled with clay, and it appears to the writer that not more than 30 per cent. of dimension stone could be recovered from this bed, or, say, 15 per cent. for the depth of the working face, though a larger proportion is fit for rubble masonry. The stone is won by blasting and by plug

and feather work. Large blocks are allowed to lie for some time to season and allow flaws and pipes to become visible. The latter, if small, may be "stopped" in ashlar work.

The stone is fairly compact, and as a whole uniform in grain, though larger shells may be scattered through the ground mass or occur as definite layers. The latter are rejected in good work. It can be effectively scabbled or sawn to ashlar blocks.

The color is light buff to yellowish, and does not alter on exposure, except that porous and absorbent stones gradually blacken owing to organic growths. The stone has been used largely in the vicinity for building, and in Adelaide for many public buildings, either as the principal material or in the form of dressings for buildings constructed mainly of slate. Examples are the Art Gallery and Museum, North Terrace; the Register building, Grenfell Street; Education Building, Flinders Street; and the superstructure of St. Peter's Cathedral. As dressings it may be seen on the Government Printing Office, King William Road.

The same class of stone was worked at Sunnyside, in the hundred of Burdett, opposite the Mypolonga landing. The quarry, which was not seen by the writer, was opened to provide material for the towers and spires of St. Peter's Cathedral.

There is undoubtedly a very large quantity of this excellent and easily dressed stone available, but the proportion of waste to be handled in winning the stone is very high, and adds to the cost of dimension stone. Possibly as the quarries extend into the cliff the honeycombing will become less pronounced, though, the beds being above water level, this feature will always be present to reduce the proportion of recoverable stone.

Inspection of some of the older buildings show that the stone should not be deeply carved or ornamented where exposed to the weather, as it frets owing to the absorption of water, but is best used in plain and bold designs. It also shows a tendency to fail under transverse stresses when used to span wide openings.

COUNTY OF STURT.

Section 7075, Hundred of Tungkillo.

A bed of marble, dipping about 45° to the eastward, crosses the Palmer Road near the centre of section 7075.

No outcrop is visible owing to the soil cover, but a small quarry on the south side of the road and two on the north side expose the bed. The latter has a width of at least a chain, with a micaceous schist bed about 15ft. to 20ft. thick dividing it. The quarry has only been opened to a depth of a few feet, and the rock blasted out for lime burning, so that no opportunity was afforded to see what sized blocks could be won.

The normal type is a very coarsely crystalline marble, grey to dark-grey in color. Some is fine in grain, and the color ranges to white, white and light-grey with yellowish-brown patches, and to dark-grey with brown patches.

An average sample has the composition shown on page 37.

The bed is reported to be traceable for a mile to the southward. So far it has only been worked for lime, but if scabbled it would make a very handsome durable building stone. Probably it would polish fairly well, if there were no objection to a coarsely crystalline surface.

It is within three miles of the Mount Pleasant railway.

COUNTY OF TAUNTON.

Parachilna Limestone.

In the Cambrian rocks of the Flinders Ranges, near Parachilna, occurs a greyish limestone, containing very abundant Archaeocyathinae fossils. The fossils are in various shades of brown.

Sawn and polished the effect is very good, but the examples in the possession of the department are all obviously from surface stones, and all show cracks and voids imperfectly filled with carbonate, which require stopping and which detract from the stone.

If search were made along the outcrop it might be possible to obtain sound stone, which, owing to its pattern, would have a commercial value, despite the distance of the deposit from the centres of population (340 miles).

SERPENTINE MARBLES.

The Pre-Cambrian metamorphic rocks developed in the Mount Lofty Ranges near Williamstown and the eastern portion of Eyre Peninsula include many marbles. In some instances these marbles are serpentinised, and would form very handsome decorative stones, if worked.

A specimen in the possession of the department from Mount Crawford, hundred of Para Wirra, county Adelaide, is a medium-grained marble, with a good deal of fine crushing and recementing of the particles. The color is a very light pale green, with darker green veins and patches.

Another specimen from the hills to the west of Tumby Bay, county of Flinders, is a fairly fine-grained white marble, which has suffered partial alteration into serpentine. The latter is both dark olive and light green in color, and evidently the stone is predominantly a white marble, with green veins and blotches.

COUNTY OF JERVOIS.

Section 1B, Hundred of Minbrie.

On this section is a steeply inclined bed of white to bluish-white magnesian marble, which contains zones of serpentine of light to medium green color. The serpentine has undergone a further alteration to chrysotile asbestos, which occurs through portions of it as narrow veins.

There is no doubt but that some very handsome decorative stone can be won from this deposit, which is within 6½ miles of a shipping port by a main road, all down grade or level.

The marble, more or less serpentinised, outcrops on two hills. The strike of the bed is approximately south-west by west. A considerable amount of work has been done in the search for bodies of asbestos, which occurs as veins and veinlets in the more crushed and highly serpentinised portions of the marble.

The north-eastern hill has a large pegmatite dyke for its core, and on the north-west of this dyke is an extensive deposit of more or less serpentinised marble, with some crush zones from which a little asbestos has been recovered. About halfway down the north-western slope is a smaller pegmatite dyke following approximately the contour of the hill. Between this dyke and the marble, and on the outer side of the dyke, is an extensive deposit of greenish-grey steatite or talc schist.

The original magnesian marble is white to bluish-white in color, and fairly fine grained. Metamorphism has resulted in a more or less complete alteration to serpentine, which is normally light greenish-yellow, but ranges

to olive green in color. This alteration has not been uniform, so that the stone is mottled, streaked, or in places completely altered. It is notably free from quartz veins (the so-called glass veins of the marble worker), so that there will be no difficulty in sawing and polishing the stone. Polished pieces indicate its suitability for furniture, and, in the writer's opinion, it would be extremely effective as panelling or wainscotting in public and office buildings. No exactly similar stone is figured in "Building and Ornamental Stones of Australia," by R. T. Baker, so that, if the stone becomes favorably known, it should have a field of its own to exploit.

Some portions of the deposit, notably along the northern side of the main asbestos open cut, are fractured, but it is equally apparent that other portions are capable of yielding large blocks.

Facilities.—The deposits are within six and a half to seven miles of the jetty at Cowell, by a good down-grade road, and transport should be obtainable in this well-established farming district for a shilling per ton mile.

Vessels up to about 12ft. draught use the harbor, there being a weekly steamer to Adelaide. Probably, if the demand warranted, sailing craft could be obtained to lift a cargo. Both hills afford suitable sites for quarrying, and the choice would probably be governed by the precise type of material called for by the market. To this end polished samples should be prepared and submitted to marble workers and architects.

The chief item of equipment required would be a hand crane capable of lifting about three tons and the usual quarrying tools.

FREESTONE AND SANDSTONE.

COUNTY OF ADELAIDE.

HUNDRED OF ADELAIDE, SECTION 943.

Sheaoak Hill Quarry (Stone Bros., lessees).

The Sheaoak Hill freestone quarry is situated on the southern boundary of the section, close to the road along the ridge between the valley of Brownhill Creek and the National Park.

The bed worked is about 20ft. to 25ft. thick, and lies on clay slate. The bed dips to the southward about 1 in 4, or a little less, and has been quarried for about 150yds. along the outcrop. The face shows from 10ft. to 16ft. of overburden, consisting of decomposed sandstone, somewhat more argillaceous than the freestone, and with intercalated clayey beds.

The freestone is variable in hardness, ranging from exceedingly friable to a stone sufficiently hard to be unpopular with the stonecutters. It has been felspathic quartzite, but the felspar has decomposed to clay in the most friable, and slightly less completely in the hardest of the rock. It is traversed by two systems of vertical jointing approximately at right angles, that facilitate quarrying.

Progress of the quarry to the eastward and to the south in the eastern portion is blocked by the road, which follows the outcrop for at least half a mile to the eastward.

The western half of the quarry is approaching the road in a southerly direction, but to the west there is no interference by the road for some distance. The stone in the western face is considerably harder, and likely to prove a much more durable and better stone than the bulk of that quarried. Though by no means hard as sandstones go, it is "not used

unless specified by the architect," on account of the additional cost of cutting.

The stone is very light pink, white, and yellow, and these colors are stated to be permanent.

HUNDRED OF ADELAIDE.

Brownhill Creek Quarry, Reserve C.

An extensive quarry has been worked for freestone on this reserve, and is credited with having produced a very good durable building stone, examples of which may be seen in many of the older buildings of Mitcham, and in the city in the upper portion of 45, Currie Street. The base courses of this building consist of brown sandstone from King's (formerly Prince's) quarry at Mitcham.

The stone is rather variable, ranging in size from a fine-grained sandstone to a medium grit, and is fairly friable. The color also varies—some is white, much is stained with iron, and some of the blocks that have been long exposed have lost the iron superficially.

The stone at Quarry Reserve C occurs as a bed about 40ft. in thickness. dipping 30° to the S.W. into a hill. The stone has been worked for several hundred feet along the strike, until the overburden became too heavy. The overburden consists of slate, arenaceous in its lower portion. To the S.E. the stone appears to cut out, as a quarry beyond on the line of strike shows argillaceous rock dipping to the S.E.

HUNDRED OF ADELAIDE.

National Park—Government Quarry Reserve.

A number of shallow and irregular quarries were worked in the past on this reserve. The bed worked lies with the slope of the hill, and dips about 10° to W.S.W. It consists of argillaceous fine-grained quartzite, so decomposed as to be soft and easily broken, and is white in color. The bed is associated with decomposed siliceous slates, and is much jointed. In addition, it is irregular horizontally, some portions being fairly thick bedded, while the same layer, but a few yards distant, is so thin bedded as to be useless as a building stone. Apparently the best patches of stone have been removed, and what is left is either covered by a large proportion of overburden or is fractured to such an extent as to be worthless. The possibilities of the quarry are very small.

HUNDRED OF ADELAIDE, SECTIONS 1161 AND 1172.

Youlton's Little Mount Lofty Quarry.

A triangular area of about 25 acres in the eastern portion of these sections includes the top of Little Mount Lofty, which is composed of freestone.

This freestone appears to have been derived from a slightly argillaceous quartzite, in which was a little ferrous iron. The beds dip at 5° to 10° to the S. and S.S.E., and are from 1ft. to 6ft. thick, with partings of decomposed argillaceous rock up to a few inches in thickness. The total thickness is not less than 50ft., and probably is considerably more. There are also two well-defined systems of vertical jointing, approximately at right angles to one another, and sufficiently spaced to give large blocks of stone.

Exposures on the south side of the deepest beds show incipient decay of a quartzite with the bluish-green tinge due to ferrous salts. Higher up the rock is softer, and mottled pink and bluish-green. Above these the

stone is the still softer workable freestone, in which pink, cream, and yellow hues predominate. Some of the cream and yellow is freckled with darker brown spots, the effect of which is pleasing and distinctive.

In texture, the freestone is fairly fine grained and uniform. It is harder than the majority of the Mount Lofty freestones, but dresses without difficulty, and is stated to be a durable and non-fretting stone.

Some 11,000 tons are reported to have been sent away from this quarry, and there is no doubt but that there are many times this quantity of stone yet to be won. Waste varies in amount, and is estimated to average about 30 per cent. of the material broken, a very low proportion. It has been kept off all quarry floors or possible extensions, so that the quarry is in a position to provide not only the normal stone, but a denser stone from below the worked-out layers. The best quality stone is stated to come from kernels, which are large masses, bounded by bedding partings and vertical joints, of which the corners have weathered, with migration of the iron to form a crust round the harder inner core. These cores afford an indication as to what the slightly less weathered lower bed should yield.

The quarry is well situated in respect to market, being right on the Mount Lofty ridge, with a down-grade haul to Adelaide and its suburbs.

Hundred of Noarlunga, Reserve No. 6.

Twelve-mile Quarry (W. Torode).

About 100yds. north of Aldgate Railway Station, and on the north-east side of the Mount Barker Road, is an old quarry from which stone for the Aldgate Station was taken when the line was constructed. The quarry exposes ilmenitic sandstone dipping 20° to the south-west. The stone is probably part of the same bed as that worked on section 94, half a mile to the westward, but the strike differs so that there is every probability of a fault being present between the two localities.

At the 12-mile quarry the stone breaks freely to bedding planes and parallel to the strike. It requires more care to break it on the dip. The bottom of the old quarry shows fairly hard but even-textured stone of light to medium grey color. It should dress without undue difficulty, and be a very durable stone.

In depth the sandstone will turn to a felspathic quartzite, as its softness and workability are proportional to the amount of decomposition that the felspar has undergone.

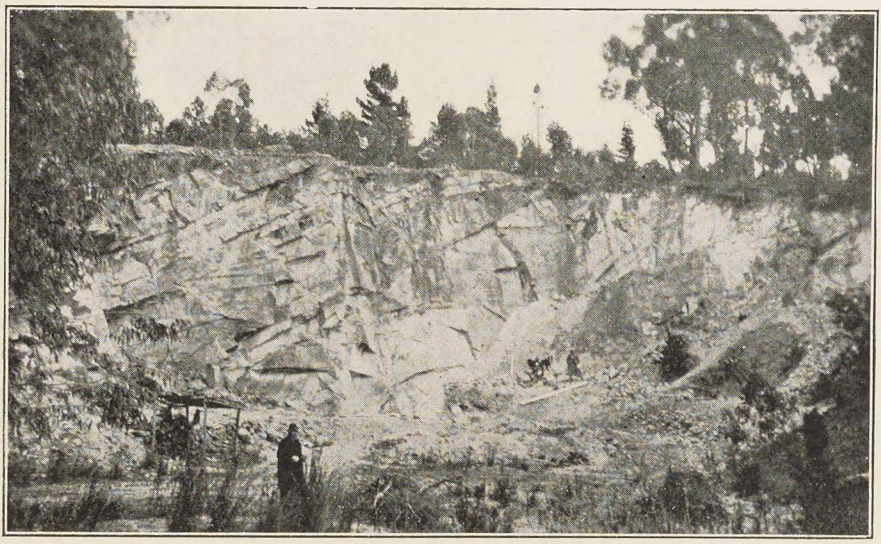
The portion removed appears to have been softer and more easily dressed. A new face now being started on the roadside just north-west of the old quarry shows this softer stone, of greyish color. Fairly soft when broken, the stone hardens on exposure. It should be laid on its bed, or there is a tendency to flake.

Hundred of Noarlunga, Part of Section 94.

Ackland's (Formerly W. Torode's) Stirling Quarry.

A light-grey freestone is worked on this section, and has provided a large quantity of building stone from a quarry some 100yds. x 40yds. in area, and up to 50ft. to 60ft. in height.

The bed has a width of about 60ft. or even more, as the harder hanging wall stone has not yet been broken. It dips 35° to E. 40° S. The footwall



Freestone Quarry, near Stirling, Hundred of Noarlunga.

Freestone Quarry at Mount Lofty, Section 402, Hundred of Noarlunga.

To face p. 59.]

is somewhat argillaceous sandstone, much colored by iron oxides, and showing a tendency to flake.

The bed itself is composed of layers 3ft. to 6ft. thick of slightly argillaceous sandstone, of which the individual layers vary in the size of the component sand grains. Current bedding is well developed, and this bedding appears in many parts to be the main parting. In the bedding are numerous ilmenite partings.

The bed is part of the Pre-Cambrian complex of the Mount Lofty Ranges, and the freestone is doubtless the weathered portion of an arkose sandstone or even a quartzite. Weathering has proceeded so far that the stone absorbs water freely, and becomes very soft. Indeed, when the quarry was visited after wet weather, no freshly broken piece was seen that could not be crumbled in the fingers. This makes for ease of quarrying and cutting, and, coupled with the property of hardening considerably on the loss of its quarry water, has led to its extensive use. It has been much used in the locality of the quarry and in Adelaide for good-class residences; and two public buildings in Adelaide—the Allan Campbell wing of the Children's Hospital and the Elder Conservatorium of the University—afford examples of its use. The latter, built in 1902, shows that the stone hardens and stands well in vertical walls, retaining the dressed surface unimpaired, but that in buttresses, corners, and carved cornices, it absorbs rainfall, softens, and shows a tendency to perish.

The stone breaks freely and easily in any direction, and stands well when it is not laid where it can absorb large quantities of water.

The waste of the quarry, which largely crumbled to sand was, during the period of more active operation, screened and used as building sand.

The outcrop extends both north-east and south-west, and there is no doubt but that the bed is capable of furnishing considerable supplies of similar material if called upon. It is stated that the quarry was at one time considerably deeper, and that the best stone came from below the level of the present floor.

Hundred of Noarlunga, Section 402.

The Mount Lofty Freestone Quarries.

This section, which includes a hill to the south of Mount Lofty Railway Station, is traversed by a thick bed of sandstone dipping 40° to 45° to E. 35° S. or into the hill. Both the dip and strike vary slightly. The section has been subdivided, and the smaller areas having passed into different ownerships, the quarries are worked independently.

Above the workable beds, which exceed 150ft. in thickness, lies a quartzitic schist, and below the beds are decomposed argillaceous rocks. The workable bed has all the appearance of having resulted from the weathering of an arkose quartzite, the felspar being weathered to a clay.

As mentioned above, the dip is into the hill, but there are several parallel joints striking with the bed and dipping 70° to 80° to the north-west. These very pronounced joints may carry several inches of crushed rock or even vein quartz, and afford facilities for freeing the stone from its bed. Minor joints of this system and of a cross system also carry quartz veins, but are not regarded as detrimental, as the beds break to these veins, and the quartz falls away from the stones, or can be easily removed in dressing.

Pink's quarry, the north-easternmost, on subsection 39 of section 402, had been worked extensively over a considerable length near the surface and into the hanging wall. Present operations are confined to the opening of a lower bench from the footwall side. The stone varies in hardness, grain, and color. Most of the stone worked is soft and yellowish to white in color, but a layer of iron-stained stone of purplish tinge has come in. This is, on the whole, harder, and there are less decomposed stones of normal color that are regarded as too hard for dressing. Both the color and the hardness show that the leaching and softening are from the surface downwards. To the south of this quarry a small opening is stated to have yielded large blocks when required.

Subsections 40 and 41 (Ackland's and Halliday's quarries) and subsection 42 (Wakefield's quarry) are to the south-west of Pink's quarry.

The stone is soft and is white, pink, and yellow, with intermediate shades. It is sold on color, and six shades are recognised. Though the stone is soft and very easily dressed and faced when freshly quarried, it hardens on exposure, and forms a satisfactory wall for residences, &c., of no great height. The size of the openings in Pink's, Ackland's, Halliday's, and Wakefield's quarries shows that the stone has been very extensively used. It is stated that some 75 per cent. of the material broken is saleable as building stone. Situated alongside and above the Mount Lofty Station, it is readily transported to Adelaide and suburbs, either by rail or road.

The railway stations in the vicinity, the entrances of the tunnels near Mount Lofty, and many residences near the quarries and in Adelaide are built of this stone.

It is used dressed, hammer-faced, or scabbled, or in the form of random rubble, known locally as crazy work.

It appears to stand well, especially when protected by overhanging roofs.

Hundred of Yatala, Section 2105.

Teisserie's Quarries.

Two quarries are situated on the south side of a gully at the north-west corner of the section, and produce quartzite road metal and a quantity of selected building stone. The eastern quarry has a slate footwall dipping 40° to the eastward, and is on a gritty to fine grained quartzite with an argillaceous matrix. The bed is about 30ft. in thickness, and is folded into a syncline. Near the surface decay of the argillaceous matrix has converted a coarser bed into a workable freestone of good quality, and of a very light-grey color, with faint yellow specks of iron-stain. The freestone is jointed into rhomboids in this quarry, and requires trimming. A proportion of slatey material is broken in winning the harder stone.

The western quarry is also on a syncline, and appears to be on the same bed. The west leg dips about 40° to the east, and is separated from the east leg, which is almost vertical, by a fault. The eastern leg is harder, and furnishes the bulk of the road metal, while the western one yields a finer-grained argillaceous quartzite, breaking into rectangular blocks and readily trimmed. The western portion of the face has reached the limits of the quarry property, but the stone continues into the adjoining section.

Yatala Stockade Quarries.

3037 *and* 3038, *Hundred of Yatala.*

From the establishment of the Yatala Prison quarrying has been one of the industries carried on. Dry Creek, trending W.N.W., separates sections 3037 and 3038, hundred of Yatala, and forms a fairly deep valley.

The creek crosses the longer axes of a series of anticlines and synclines in the Cambrian quartzites and slates. The pitch of these structural folds is to the southward, and is greatest at the western end of the sections. The easternmost syncline or quartzite, about half a mile to the east, is only pitching very flatly, and the quarries on it give promise of very considerable longitudinal extension.

The principal output of the quarries are a high-grade quartzite road metal, and a clay slate, which is disposed of to a cement factory. The eastern syncline is now the site of the main quarry. It produces a white to greyish quartzite of fine to medium grain. The folding has developed cross jointing, and in parts these joints and the bedding permit of approximately rectangular blocks being obtained and disposed of as "builders," which are used principally for the lower courses of walls between the foundation stones and the brick superstructure. The westernmost quarry, now abandoned owing to the dip of the legs and the pitch of the anticline towards the buildings, has produced thinner bedded fine-grained blue quartzite and a more argillaceous quartzite. This and the quartzite, semi-decomposed argillaceous quartzite, and some slate from the "Bath quarry," have been utilised extensively in building the prison. Examples dating from 1854 were examined. Current bedding and ripple marks are developed in some of the stone, as well as a tendency for cleavage structure to cross the bedding planes. A few of the softer stones, such as the slate and the quartzite decomposed to sandstone on the outcrop, show traces of weathering on these cleavages, but the bulk of the stone is unaffected. The normal color is a light grey, with red and brown iron coloration on the joint planes. These planes are utilised as "facers."

The clay slate is worked separately in one quarry for a cement works, and large blocks of slate are obtained for foundation blocks.

At some of the other, or quartzite quarries, the slate is also trucked to the cement works when free of quartz veins or lenticles of quartzite. Such material is disposed of as ballast, or for the foundation bed of roads. To sum up, the quarries produce for the builder:—

(1) Raw material for cement factory.
(2) Foundation blocks (slate).
(3) A proportion of slate, quartzite, and quartzitic sandstone blocks, of sizes that require but little dressing to fit them for random course rubble walls. They are, for the most part, very durable in the walls, the only sign of weathering being in the cleaved argillaceous rocks.

Sections 5397 and 5640, Hundred of Yatala.

Teatree Gully Sandstone and Freestone Quarries.

The lowest beds of the Cambrian series consist of felspathic grits and quartzites, and these, by decay of the felspar, may become soft enough to be used as freestone.

The bed that has been principally worked at Teatree Gully trends in a N.E.-S.W. direction through section 5397, hundred of Yatala, and dips to the south-east, at about 40°, into the hill. The outcrop is of considerable width, and only the westernmost portion has been worked. Along this portion, for a distance of approximately half a mile, are St. Peter's or Torode's quarry, G. Hannaford's quarry, and Bundey's quarry. The latter has not been worked for many years.

Bedding planes, some of which are more in the nature of argillaceous bands, enable the stone to be broken out, and this process is facilitated by the presence of transverse vertical joints and joints parallel to the strike. There are also irregular joints that reduce the percentage of recoverable stone.

The bed worked was originally a felspathic quartzite, and parts of it carry finely disseminated pyrite. Weathering has affected the outcrop, and has been assisted by the presence of the joints referred to above. As a result a section of the quarries shows soil or superficially hardened and iron-stained stone, below which is decomposed rock, some of which may be too soft for good work and other portions, such as were insufficiently fractured, too hard to dress, with cores of quartzite in a joint-faced block of stone. The bulk of the zone is, however, soft enough to be workable. As depth is attained there is a progressive hardening, which continues until the unaltered quartzite is, or will be, reached. The softest stone is used for smaller buildings, and the harder (limited by the cost of dressing) for more important edifices.

The color is variable. The two chief types are the white and a light brown merging on the one hand to a darker brown, and on the other to a yellow. There is in parts a concentric segregation of the iron coloring matter that is very effective on dressed faces.

Another quarry (J. Hannaford's) was worked on section 5640, hundred of Yatala, apparently on the other leg of the anticline formed by the felspathic quartzite. This stone, which is much cut up by joints, is very friable, and the iron has collected into sand-filled shells of limonite in the most friable portions. Below this very friable bed, better quality (harder) stone was visible in the floor, but the rock is too jointed to yield large blocks.

An old quarry (Brown & Thompson's) to the north, but on the same section, was seen, from which the writer was informed that white stone had been used in the Adelaide Town Hall, the Post Office, stone dressings in the Flinders Street Baptist Church, and part of St. Peter's Cathedral. The quarry seen was only about 80ft. x 30ft. x 20ft., too small to have yielded so much stone, but other scattered quarries were visible to the north and west.

The outcrop on section 5397 yielded brown stone from the present St. Peter's quarry and from Bundey's quarry for St. Peter's College and the Cathedral.

This stone has every appearance of durability, and is the strongest of the sandstones from the Mount Lofty Ranges that are generally used. At the same time it should be recognised that in the majority of cases cost, and not quality, is the controlling factor, and the harder and more durable stone is left in some of the quarries as being "too hard for the stonecutter to work." There is no doubt whatever as to the presence of harder and more durable stone lower down the dip of even the softest freestone beds worked.

At the Teatree Gully quarries the proportion of waste is very considerable; in part due to the the more exacting demands made by public buildings for larger and harder stone than is required by smaller buildings, and in

part by the presence of harder zones and masses in the usable stone. The merchantable stone appears to vary from 25 per cent. to 40 per cent. of that broken.

Transport is by road, a distance of about 14 miles from the centre of Adelaide.

COUNTY OF GAWLER.

Section 420, Hundred of Alma.

This quarry was not visited, but the following notes were obtained from the operator (W. H. Durdan), who supplied specimens to the writer.

The deposit is said to be large and to have supplied several thousand yards of stone. At the present time some 500 yards are being taken out for a Roman Catholic Church at Hamley Bridge.

The stone is white to cream in color, and, like the other siliceous freestones of the State, consists of quartz grains cemented by kaolin derived from the decomposition of the felspar of a felspathic quartzite. Blocks of several cubic feet are obtained when required. The stone is very soft, and easily broken and worked when fresh, but hardens on exposure. It is said to resist weathering well, and examples of its use in Tarlee confirmed this statement. Probably, as in the case of other quarries supplying this type of stone, deeper workings on the bed would yield a harder stone.

COUNTY OF HAMLEY.

Spring Cart Gully Quarries.†

These quarries are situated on the right bank of the River Murray, in the County of Hamley, about eight miles S.W. of Renmark.

The quarrying operations have been carried on for a distance of about half a mile along the cliff banks of the river, about 40ft. above river level. The bed of stone averages 4ft., the maximum thickness being about 7ft. The average depth of overburden is about 5ft., increasing in places to as much as 10ft.

It is stated to be the only freestone quarry* suitable for building material between Renmark and Murray Bridge, and has been considerably drawn on for building purposes in the Murray settlements—Renmark, Berri, &c. The police station, churches, and other buildings at Renmark have been erected with this stone.

The freestone is composed of well water-worn quartz grains cemented together by travertinous carbonate of lime, but with a very considerable proportion of the pore space between the grains unfilled. The finer grained stone is made up of quartz grains of about 20-30 mesh size, and the coarser of grains of about 10 to 15 mesh, and the grains are very uniform.

The color ranges from white to light yellow, according to the proportion of iron present. The stone is curiously suited to its environment. In a cold, wet climate, and especially in a city, it would soon suffer from mechanical and chemical disintegration. In the Murray Valley the dryness and purity of the atmosphere will not affect the stone, and it is probable that the porosity is of marked benefit in checking the transmission of heat through walls. The stone is easy to shape, and is obtainable in fair-sized blocks.

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* The so-called "freestone," or polyzoal limestone, of Burdett occurs above Murray Bridge, and has been worked opposite Mypolonga.

† Information supplied by the Chief Inspector of Mines.

COUNTY OF HINDMARSH.

Section 2325, Hundred of Nangkita and Section 2328, Hundred of Kondoparinga.

Finniss River Sandstone.

Stone has been brought to Adelaide for some of the larger buildings from sections 2325, hundred of Nangkita, and 2328, hundred of Kondoparinga. The two sections are separated by the River Finniss, which has cut through an overlying bed of water-worn gravel, believed to be of late Tertiary age. This rests upon a yellowish to greyish and bluish mottled sandy clay, containing scattered pebbles and stones; portion of the glacial series considered to be of Permo-Carboniferous age.

Two quarries have been worked on section 2325, and the northern one shows a bed, about 10ft. thick, of building stone, apparently striking N. 100° and dipping 80° to the northwards. This stone is capped by the mottled clay, which also shows on the south side or footwall of the bed. The building stone, at its cap, is an argillaceous sandstone, which gradually becomes harder until it is a fairly dense quartzite, with specks of argillaceous material that are apparently due to the decomposition of fine-grained felspar. The quarry, however, which is very shallow, has not reached this harder rock. The south quarry has a length of 120ft., and the bulk of the face is clay with pebbles. The top of the quarry shows a few feet of Tertiary gravel resting on the clay, and on an embedded mass of convoluted sandstone about 10ft. by 30ft. This is separated from the lower or main sandstone by 10ft. of grey arenaceous clay containing pebbles. The main sandstone rises to a height of 15ft. above the quarry floor, and the latter shows the above-described quartzite. The sandstone-quartzite bed has nearly vertical joints striking 30° N. of W., and weathering shows flatly dipping planes dipping to 30° S. of W. The useful stone is from 20ft. to 30ft. wide. The impression given by these two quarries is that the stone itself, though closely associated with the Permo-Carboniferous till, is a decomposed uptilted quartzite of much greater age—similar in type to the freestones of the Mount Lofty Ranges.

On the left bank of the river (section 2328, hundred of Kondoparinga), on a bearing of E. 25° S. from the last-described quarry, is a very shallow quarry where the stone is capped by shingle. The stone here has the appearance of being horizontally bedded with vertical joints, and is grey to buff in color and fairly hard.

The northern quarry of this section shows a convoluted and current bedded argillaceous sandstone, much softer than that exposed elsewhere, closely associated with arenaceous glacial clay. This and the convoluted sandstone mass seen in the south quarry across the river may indeed be Permo-carboniferous, but the deeper stone of the western quarries is certainly not. The stone of this quarry is too soft for good building, and examples in Adelaide, such as the Bank of New South Wales and a pillar in the gateway of the University, are not entirely satisfactory. Yet it must be assumed that unduly soft stone was taken from the surface, as the deeper stone on the right bank quarries and the stone in the southern quarry on the left bank are far above the quality of that exposed in the buildings above referred to. Ease of working, rather than durability, must have influenced the selection of the stone.

The quantity available does not appear to be very great, the southern quarry on the left bank (section 2328, hundred of Kondoparinga) affording the greatest promise of easily won supplies.

COUNTY OF STANLEY.

Section 423, Hundred of Clare.

Knapstein's Quarries.

Freestone (decomposed felspathic quartzite) has been quarried on a small scale in several places on this section. Some of the material has a pinkish tinge like the Sheaoak Hill (section 943, Noarlunga) freestone; other portions are white. The quantity is evidently very large, but the joint systems of the district will affect the size of the blocks and increase the proportion of waste. It appears improbable that these freestones will be extensively used in the metropolitan area, which has supplies of similar stone close at hand.

Section 3038, Hundred of Clare.

Ayer's Quarry.

A quarry about 40ft. in width has been opened on a bed of quartzite, vertical in attitude, and striking N.N.W.

The stone is felspathic, and the decomposition of the felspar yields a freestone of medium grain, with a slightly greyish tinge. It resembles the harder freestone of the Stirling quarry (section 94, Noarlunga) very closely. The rock, as in other exposures on the same line, is fractured by a system of joints dipping 30° E., and from 2in. to a foot apart. Consequently no large blocks are obtainable, and there is a considerable wastage. Some examples of its use may be seen in Clare, prominent among which is the war memorial gateway recently erected.

COUNTY OF VICTORIA.

Hundred of Napperby, Section 24.

Young's Quarry.

This quarry was not seen by the writer, who is indebted to the Chief Inspector of Mines for the description published below.

A large amount of building stone from this quarry has been used in Port Pirie.

The stone is an easily worked felspathic sandstone, and observation of its use shows that it is durable when laid properly on its quarry bed. An example was seen where this stone had been laid on edge, and was flaking considerably.

The quarry is about 12 miles south of east from Port Pirie, in the low hills, where the older rocks rise above the level of the coastal plain. A cut has been made into the hill for about five chains in an east-west direction, in order to obtain the stone which dips to the south at an angle of 25°. The overburden consists of about 5ft. of soil and weathered stone, over a face of stone about 15ft. high. There is a nearly vertical cleavage, the planes, however, being far enough apart to allow of large blocks being obtained. The stone is white in some parts of the quarry, and varying shades of brown in others. The texture varies, ranging from very fine to fairly coarse quartz grains, with a somewhat variable amount of kaolin as a cementing medium.

Examples of its use are the front portion of the Port Pirie Institute building (the rear portion is built of stone from another quarry), the foundation courses of the Savings Bank of South Australia, Norman Street, Port Pirie, and also of the A.M.P. building in the same street. A portion of Prest's Buildings, in the same street, has also been built of this stone.

GRANITE.

COUNTY OF HINDMARSH.

HUNDREDS OF ENCOUNTER BAY AND GOOLWA.

The Encounter Bay Granites.

A group of granite islands and headlands extends for some distance along the north-western margin of Encounter Bay and the vicinity, and has yielded a very fine building stone. The granite occurs at West Island (reserved by the Architect-in-Chief's Department), the Bluff or Rosetta Head (reserve), Wright Island, Granite Island (reserve of the S.A.R. and Marine Board), Seal Rock, Port Elliot (reserve of the S.A.R. and park lands), and Commodore Point, to the eastward of Port Elliot.

The Bluff, Granite Island, and the foreshores of Port Elliot cannot be considered as possible sources of building stone, unless for the extension of the breakwaters at the two latter localities, while Wright Island and Seal Rock are inaccessible.

An intensive petrological study of this group of granite exposures and the associated igneous rocks has been made by W. R. Browne, B.Sc. (Vol. XLIV., Proc. Roy. Soc. S.A., 1920). The following notes deal with the rock as a building stone rather than from the petrological side.

West Island is a reserve for the purposes of supplying the requirements of the Government for a building granite, but Commodore Point and the extension north-eastwards of the shore in section 2311, hundred of Goolwa, appear to offer a mainland site for a quarry within a mile of a railway station and beyond the risk of danger to the town. The mineral rights of this section are alienated from the Crown.

The quarry from which the steps and base courses of Parliament House and the bases of the Banks of New South Wales and Australasia were obtained is situated on West Island, and was visited by the writer. The island, which has an area of 25 acres, and a maximum height of 132ft., is wholly composed of a very uniform coarse-grained granite, with large porphyritic crystals of microline felspar. The ground mass consists of bluish opalescent quartz, biotite, and felspar, in which are embedded phenocrysts of felspar, which may reach a length of 2in. and a diameter of 1½in. The stone as a whole is grey in color.

The quarry is opened on the N.N.W. or sheltered side of the island, and a jetty of about 30ft. in length extends into water sufficient for the boats that used to take the stone. The jetty would require to be largely renewed before the quarry could produce again.

The granite is cut by several joint systems, which are sufficiently far apart not to prejudicially affect the stone. The most important is a series dipping 20° to the westward at intervals of 10ft. to 15ft., and which serve as floors to work to. The other joint systems are nearly vertical, and strike 10°, 70°, and 110° east of north. The granite contains occasional pieces of included schist caught up when it was injected into the Pre-Cambrian rocks, but the proportion is so small that there is no difficulty in getting a face free of inclusions. Much larger inclusions occur on the seaward side of the Bluff (Rosetta Head), and at the wharf there the contact between the granite and the schist can be studied.

On the south-west end of West Island is a small pegmatitic dyke, and occasional small irregular segregations can be found. The granite is for the most part bare and unweathered to the very surface, but is stained to a depth of 3in. to 4in. It breaks up by exfoliation and disintegration to a quartz and felspar gravel, rather than by decomposition. On the N.W. side of

the island are four to five acres of calcareous sand, but it is shallow and of little consequence except as a possible site for a small soakage of fresh water.

When the quarry was in operation the stone was largely dressed on the island, and shipped in finished form, and this would probably be done when the quarry is again worked. A sample of chippings from the dressing floors was taken for analysis, and the result is given on page 68. There is no doubt as to the beauty and durability of this granite, and no practical limit to the supply available. It might be used to advantage in conjunction with the Monarto granite, with which it would harmonise in color and contrast in texture. Stones of any size that can be handled can be obtained. The quarry is favorably situated with regard to transport, being alongside a wharf and within 100 miles of Adelaide by sea. It is also favorably situated in respect to Victorian ports, where, however, it would have to meet a similar, but finer-grained, granite (from Harcourt) in competition.

The same type of granite is well exposed at Granite Island in the quarry from which material for the breakwater was taken. An analysis of this material by W. R. Browne is quoted on page 68,* and may be compared with the sample taken by the writer from West Island. No rock is likely to be worked on Granite Island, unless for public purposes in connection with the railway or harbor, as it is a reserve maintained for shipping and recreation purposes.

Similarly the granite of the foreshores of Port Elliot, which is generally similar, is inviolable. A little to the east of Green Bay there is a development of medium-grained granite, with even-sized blue quartz and felspar crystals, that is of high quality. A quarry was started on this in 1881, but operations were prohibited almost immediately. The faces broken then are exceptionally fresh.

Both the porphyritic and the even-grained granite occur on section 2311, hundred of Goolwa, and there could be little reasonable objection to work on this section (which is a freehold). The porphyritic granite occurs on the foreshore from Commodore Point for about 30 chains to the north-east, and then the even-grained rock comes in. The effective height above the sea is only 20ft. to 30ft., and there is a capping of blown sand, which could, however, be easily hydraulicked into the sea. This area is within easy reach of the railway, but, unless the even-grained granite were desired, could not in general compete with the West Island quarry, which is the natural source of supply for grey coarsely crystalline porphyritic granite.

COUNTY OF JERVOIS.

Hundred of Charleston.

Midgee Granite.

The greater portion of the hundred of Charleston is occupied by a granite mass, the bulk of which is coarse grained, and shows but little evidence of crushing. The felspar crystals are, on the whole, very large and of a light pinkish color. The quartz ranges from colorless to smoky. Mica is, on the whole, not very abundant, but patches show a considerable proportion of biotite.

Under the microscope it is seen to be very coarse-grained microcline granite with a little perthite and some oligoclase, and between the large microcline crystals some clear secondary felspar is present.

Much of the stone is handsome, and would undoubtedly be used if transport facilities were present.

The composition is shown on page 68.

* Proc. Royal Soc. S.A., Vol. XLIV., p. 15

	Analyses of Granites.								Analyses of Felspar Porphyries.	
	Section 960, Hundred of Tungkillo, ¾ mile west of Palmer.	Monarto granite, section 520, Hundred of Mobilong.	Swanport, section A, Hundred of Mobilong.	Granite Island, Victor Harbor. W. R. Browne (anal).	West Island. Average sample.	Midgee granite, Hundred of Charleston.	Section 5, Hundred of Moody.	Mimipa Hill.	Dark-grey felspar porphyry Paney Bluff.	Red felspar porphyry, Paney Bluff.
	%	%	%	%	%	%	%	%	%	%
Silica (SiO_2)	73·96	72·42	74·20	68·20	71·44	75·57	68·31	72·30	72·22	71·48
Alumina (Al_2O_3)	13·67	15·49	14·53	15·99	15·09	13·14	15·21	14·64	14·35	14·73
Ferric oxide (Fe_2O_3)	1·22	·44	1·14	·89	·86	·63	·53	1·21	1·22	1·14
Ferrous oxide (FeO)	1·03	1·03	·90	2·58	2·35	1·04	3·73	·24	1·69	1·16
Magnesia (MgO)	·56	·20	·20	·80	·80	·14	·65	·32	·30	·25
Lime (CaO)	1·58	1·44	1·00	2·61	1·18	Nil	1·99	·32	1·22	·54
Soda (Na_2O)	3·01	4·30	3·06	2·85	2·09	2·96	3·14	4·38	2·50	2·74
Potash (K_2O)	3·36	3·78	3·55	4·60	4·46	6·06	4·68	6·04	5·12	5·68
Water at 100°C. (H_2O)	·04	·12	·15	·64	·04	·12	·08	·20	·12	·32
Water over 100°C. (H_2O)	·29	·18	·15	·21	·24	·46	·44	·24	·68	1·08
Carbon dioxide (CO_2)	·22	·04	·11	Nil	Trace	Nil	Nil	·10	·22	·12
Titanic dioxide (TiO_2)	·37	·22	·29	·58	·53	·08	·53	·36	·42	·35
Phosphoric anhydride (P_2O_5)	·16	·19	·08	·14	·22	·06	·29	·04	·07	·04
Sulphur trioxide (SO_3)	Nil	—	—	—	—	—	—	—	—	—
Chlorine (Cl)	·02	Nil	·03	—	·05	·03	·10	·03	·02	·04
Ferric disulphide (FeS_2)	·25	·11	·10	·11	·04	·02	·09	·15	·06	·14
Manganous oxide (MnO)	·04	·02	·03	·04	·02	·05	·04	·11	·02	·10
Barium oxide (BaO)	Nil	Nil	Nil	·04	Nil	·02	Nil	—	—	—
Total	99·78	99·98	99·52	100·28	99·41	100·36	99·81	100·68	100·23	99·92

Section 3, Hundred Moody.

The Port Lincoln-Kimba Railway exposes an extensive area of granite in the hundred of Moody.

Parts of this exposure are gneissic in structure, and others show considerable variation in composition owing to the segregation of the quartz or the mica.

In section 3, hundred of Moody, however, there is a considerable outcrop that shows no evidence of crushing, and which could be readily exploited. The rock is composed of medium-sized white felspar and quartz, with a sufficiency of small biotite to give it a grey tint. Porphyritic crystals of felspar are visible but by no means numerous.

Near the boundary of sections 4 and 5 granite of similar grain but with pinkish felspar is exposed in a railway cutting.

Under the microscope the rock is seen to be a microcline biotite granite. The microcline occurs in large irregular plates. In addition there is a plagioclase felspar (oligoclase andesine), but it is relatively scarce. There is also a third felspar, of which the refractive index is less than that of Canada balsam. A little perthite is present. The relatively late crystallisation of the microcline and perthite is notable. The quartz and abundant biotite show irregular outlines. Granules of apatite are abundant, and are in many cases included in the biotite.

The analysis of this granite, from section 5, is given on page 68.

Situated on the railway, 62 miles from Port Lincoln, this grey granite is within economic reach, and is the best situated in respect to Adelaide. At the present time this granite is not utilised, but the extent of the area and the color are such that the material must ultimately find an application in building construction.

COUNTY OF LE HUNTE.

The Minnipa Granite.

A number of granite bosses exist within a few miles of the Port Lincoln-Cape Thevenard Railway, between Minnipa and Wudinna.

Some of these bosses are utilised as catchments for tanks, which store water for the needs of the settlers.

The type may be taken as that occurring at Minnipa Hill, and is fairly coarse grained and slightly below normal in the proportion of mica present. Reddish quartz and light-colored felspar predominate, the biotite being sparingly distributed. The stone is pink in color, and would make a very handsome and durable building material. It is, however, handicapped by the distance (157 miles) to Port Lincoln.

Microscopic examination of the granite shows the almost constant presence of microcline, and an acid plagioclase, with the extinction angles of albite-oligoclase in addition to the orthoclase. Occasional crystals of a more basic plagioclase, with the extinction angles of oliogoclase-andesine, appear in some of the sections. Perthitic intergrowths of the felspars occur in some varieties, and in rare instances a micropegmatitic intergrowth of plagioclase and quartz surrounds the albite-oligoclase. The mica is almost wholly biotite, only traces of muscovite being present. The quartz presents

no special features, but in some sections is seen to be enclosed within large plates of microcline. Sphene is relatively abundant, and is usually well crystallised, exhibiting the typical lozenge-shaped sections. The distribution of apatite is irregular.

The type granite of Minnipa Hill has the composition shown on page 68.

COUNTY OF LIGHT.

Hundred of Moorooroo, Section 444.

A very sound red granite is reported to exist on this section, and to resemble the Palmer granite.

It has been but little worked, but the pedestal carrying the bust of Lord Tennyson, in the Adelaide Art Gallery, was quoted as an example of its use. This pedestal shows the stone to be slightly gneissic in type, of medium grain, and reddish, with a tinge of yellow, in color. It closely resembles the finer-grained Palmer stone.

COUNTY OF STURT.

Hundred of Mobilong, Section A.

Swanport Granite.

A "whaleback" of granite, about 10 chains long and two clains wide, projects about 25ft. above the alluvium of the Murray flats at a point three miles S.S.E. of Murray Bridge.

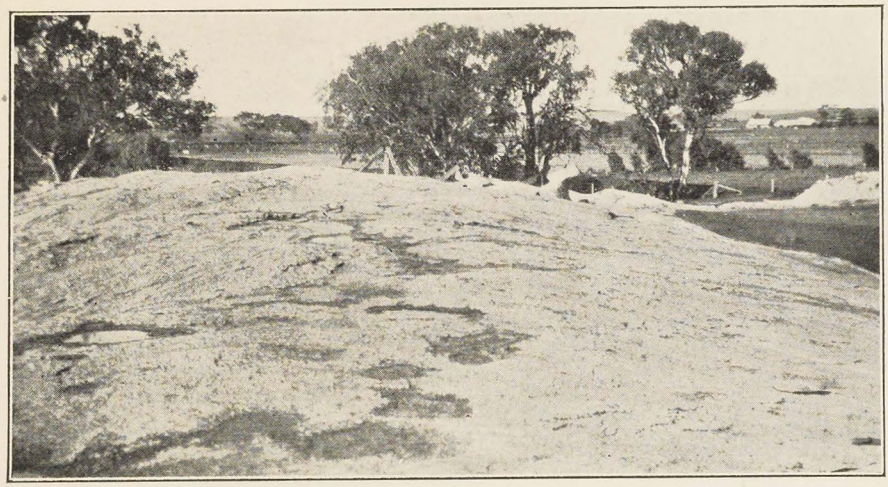
This is, perhaps, the most extensively worked granite in the State, having a pleasing reddish color (especially when polished) and a bold crystallisation. The stone is very uniform, the only variation noted being the presence of a 4in. vein of aplitic material in the western quarry.

The felspar is distinctly reddish, and the quartz is smoky to blackish. Mica (biotite) is not abundant.

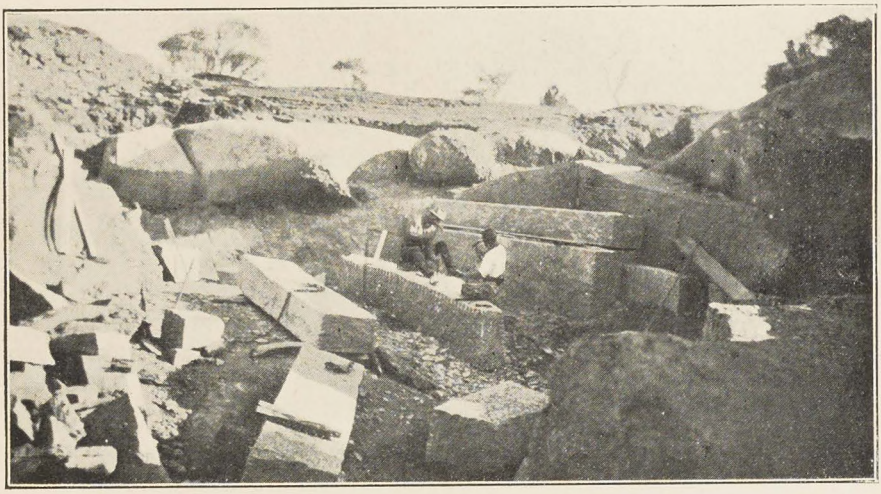
Under the microscope it is seen to be a coarse granite, with biotite showing very strong absorption. Plagioclase (oligoclase) shows small extinction angles, while orthoclase is present. Quartz appears to have filled the interstices between the earlier formed crystals.

Stone has been taken in the past from the west end of the whaleback and from boulders. The present work is being done in a small quarry at the east end. The stone is very massive, and at the time of inspection blocks 10ft. by 2ft. by 1½ft. were being split out for a memorial. So far only a small proportion of the available stone has been removed.

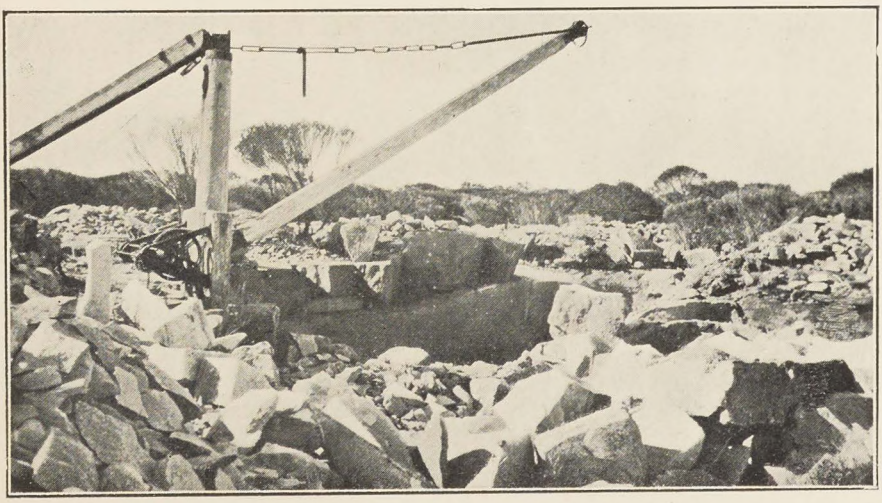
It is somewhat greyish when hammer dressed, the full color being best seen in polished work. Examples of its use are the base courses, and in some cases the steps and lower story of the Adelaide Railway Station, Education Building, Savings Bank, National Mutual Building. Norwich Union Building, and the base pedestals of the Soldiers' Monument, North Terrace; Colonel Light's and Kingston's statues, Victoria Square; and the Hughes statue at the University. It is also used for kerbs. The stone breaks truly, horizontally, and across the major axis of the deposit. Along the major axis the fracture is somewhat irregular. The stone is quarried to take advantage of these features.



Swanport Granite Outcrop, Section A.



Swanport Granite Quarry, Section A.



Monarto Granite Quarry, Section 520, Hundred of Mobilong.

To face p. 71.]

Hundred of Mobilong, Section 520.

Monarto Quarry.

Granite, of slightly gneissic habit, is exposed on sections 521, 520, 526, 527, and part of 215, over an area of a square mile and prabably considerably more.

It is traversed by the Adelaide-Melbourne railway, three and a half miles east of Monarto Station, and is 55 miles from Adelaide.

The stone is practically unaffected by weathering to the surface. Boulders on the surface or embedded have been cut up for building stone, and the quarry on section 520 shows that the soil is very shallow.

Some of the stone shows a slight yellowish tinge for a few inches from the surface, but the bulk of the rock consists of medium-grained white quartz and felspar, with black mica and a little muscovite mica.

Occasional small segregations of mica occur. The general effect is a light grey. Microscopic examination shows brownish-green biotite and some muscovite, with abundant microcline. It shows a medium-grained granite of typical structure.

The stone is hard, but splits cleanly and evenly in plug and feather work.

It has been used polished in the base courses of the Co-Operative Building Society's building in King William Street, and for kerbings. Further examples of its use are to be seen in the Norwich Union, Adelaide Steamship, and Elder, Smith, & Co.'s buildings, and in the base of Colonel Light's statue, and the steps of St. Peter's Cathedral. Greater attention may be well given to this fine-grained granite, which might might be considered complementary to the coarse grey granite of Victor Harbor. The two could be used in combination with good effect.

Hundred of Tungkillo, Section 960.

Palmer Granite.

As the village of Palmer is approached from Adelaide by the main road, numerous tor-strewn outcrops of granite are visible on either side of the road for a distance of little over half a mile. There are probably 200 acres in which the ridges and knolls are tor covered. The outcrops are about three-quarters of a mile from Palmer and three and a half miles from Apamurra Station (72½ miles from Adelaide), on the Monarto to Sedan railway. The road is down grade and a main one, so that there are no transport difficulties.

So far there has been no subsurface quarrying, though a very fair quantity of building stone has been removed. Hitherto the supply has been obtained by splitting to dimensions, with plug and feather work, the large boulders and masses that strew the surface, and this source of supply is barely touched.

The granite normally is a pale pink, of medium grain, with fairly abundant biotite mica, so arranged as to give the impression of slightly gneissic structure. Small inclusions of basic schistose material are present, but there is no great quantity. Occasional boulders are fine grained, and show the gneissic structure, but this type is very scarce.

Towards the western portion of the area the felspar becomes more porphyritic, and occurs as pale pink crystals up to half an inch across.

The material is broken out of the boulders, and it is noticeable that the rock is sound to within an inch or less of the surface of the boulder. Despite the apparent schistosity the rock appears to break readily along any desired plane, and to break very true. Large blocks can be and are obtained, and pieces up to 8ft. by 12in. by 7in. are split out for kerbing and stair treads without difficulty.

In the western portion of the area one extensive and two small quarries have been made, apparently for road material, away from the outcrop. These openings show aplite and gneiss of very variable grain, all sheeted and fractured, and showing evidence of intense strain. The material is shattered to such an extent that it is impossible that it could yield unweathered kernels comparable to those strewn on the surface. The kernels are apparently little stressed, and in all probability are weathered from the caps of granite dykes penetrating an older granite or gneiss with somewhat different physial characteristics. The exposures along the road confirm the impression that the good stone will be found as dykes. It may be seen in use as the base of the Queen's Statue, Victoria Square, and the base courses of the Executor and Trustee Company's building in Grenfell Street. It is also used for kerbing and for monumental work and memorials.

Handicapped in the past by transport difficulties, it has been used to some extent, and now that the railway is within easy reach it is only reasonable to expect that this durable and handsome stone will be used in greater amount.

The analysis of this granite is given on page 68.

DIORITE PORPHYRITE.

COUNTY OF ADELAIDE.

HUNDRED OF ONKAPARINGA, SECTIONS 5267 AND 5269.

A number of dykes penetrates the palaezoic metamorphosed sediments in these sections. They consist essentially of hornblende and felspar as a felted ground mass of dark-grey color—but showing greenish-grey when polished—in which are white porphyritic crystals of felspar. The rock may be termed a diorite-porphyrite.

Very tough and capable of taking a high polish, and apparently obtainable in large and uniformly grained blocks, the stone would be eminently desirable for base courses, pillars, and similar architectural uses, either in rock-faced or polished form. It is undoubtedly a hard and durable rock, but would be expensive to work, being perhaps comparable in this respect to the well-known Bowral "trachyte" of New South Wales.

FELSPAR PORPHYRY.

GAWLER RANGES.

A very large development of felspar porphyry forms the Gawler Ranges, and, though this rock is in all probability too dense and difficult to cut ever to be worked on an extensive scale, there are facies that merit attention for decorative purposes.

For the most part it is out of reach of transport except where it occurs near Iron Knob, and near Tarcoola, on the Port Augusta to Kalgoorlie railway.

At the first locality, about 12 miles from the railhead, there is a considerable exposure of very dense but jointed felspar porphyry of terra cotta to brownish-red color. The base contains felspar crystals of very similar color, ranging from microscopic to over half an inch across. Dark patches of chlorite add to the attractiveness of the rock. Similar material occurs at Tomato Rocks, near Tarcoola.

The felspar porphyry was also seen at Paney Station, where there are several types. Reddish, liver-colored, buff, and dark-grey material occur here. The phenocrysts consist almost entirely of felspar, in most cases having a pinkish hue. In some varieties of the rock quartz in small crystals is also visible. Chlorite in irregular patches and streaks takes the place of the ferro-magnesian constituent.

The relative abundance of the phenocrysts in the ground mass is very variable. The ground mass itself is exceedingly fine grained, and fresh specimens of the rock break with a conchoidal fracture. None of the varieties show evidence of crushing.

Microscopically these rocks show a ground mass that is invariably cryptocrystalline. In some cases there are numerous acicular microlites, and the ground mass when examined under crossed nicols shows in some cases well-defined aggregate polarisation. Both plagioclase and orthoclase appear to be represented among the phenocrysts, but without exception the felspars have suffered considerable alteration.

Haematite is abundantly disseminated in the form of dust throughout the ground mass and in the cleavages of the felspar crystals of the reddish varieties, and is the cause of their color. The ferro-magnesian constituent is a colorless pyroxene where unaltered, but in almost every instance it is chloritised.

The analyses on page 68 indicate the chemical composition. The samples were taken near Paney Bluff.

The stone is hard and durable, and takes a high polish but would be expensive to work. It would be very effective in high-class decorative work, such as columns and pannelling. An especially handsome variety has a buff-colored ground mass spotted with bright pink felspar crystals, and traversed by thin sheets and lenticles of sage-green chloritic material.

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